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Battelle Columbus Div., Washington, DC

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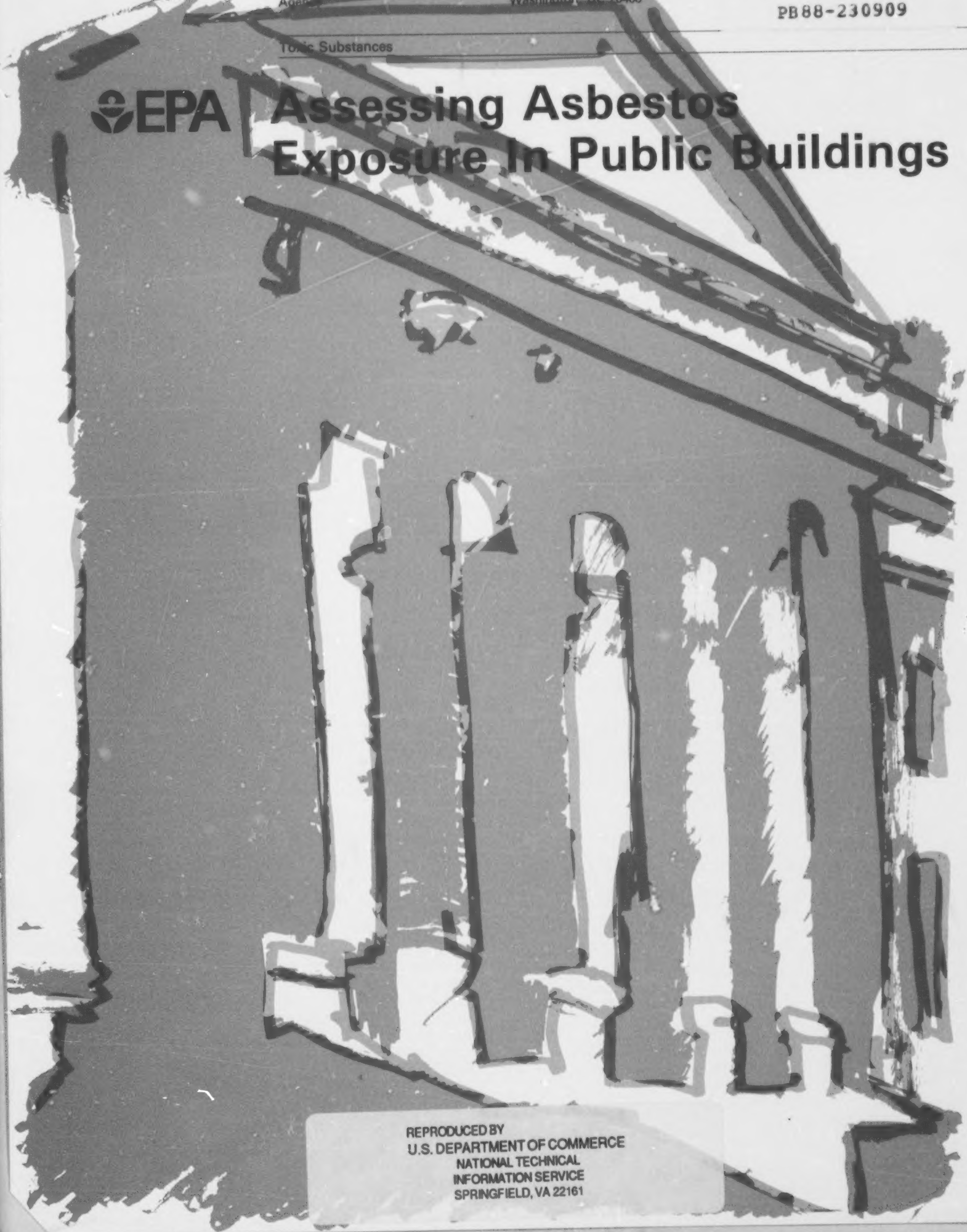

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Airborne asbestos levels were measured by direct transmissi
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buildings without asbestos-containing material (ACM); (2) buildings with al
or most of the ACM in good condition allowing for a limited number of areas
of moderate damage; and (3) buildings which had at least one area of
significantly damaged ACM or numerous areas of moderate damage. Approximate
seven areas were monitored inside and one area outside each building.
Although the absolute airborne asbestos levels were very low, Category (3)
had the highest median levels followed by Category (2), Category (1), and
outdoors. Category (3) levels were significantly higher than Category (1):

Another objective was to field test an assessment method for ACM developed
facilitate abatement decision making in the context of an asbestos manageme
program. Material condition, potential for disturbance, and air flow were
assessed by trained raters in 257 areas in 60 public buildings. Using rate
consistency as an evaluation criterion, the three factors showed promise as
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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) conducted a field study during 1987 to address a number of asbestos exposure issues. The study was designed and conducted during a period when information needs concerning asbestos in buildings were rapidly changing and expanding. Late in 1985, while administering the Asbestos School Hazard Abatement Act (ASHAA) (Public Law 98-377), EPA was asked to conduct an air monitoring study of asbestos levels in buildings. The request, submitted to the 99th Congress in a report by the House Committee on Appropriations (House Report 99-212), appropriated $500,000 for air monitoring studies when signed on November 25, 1985. These air monitoring studies were intended to provide data on asbestos exposure levels inside buildings with asbestos-containing materials (ACM) and ambient outdoor levels. In response to this request, EPA began planning an air monitoring study to be conducted in the latter part of 1986 and early 1987.

Simultaneously, EPA was engaged in the development of an assessment method for differentiating areas of ACM requiring immediate abatement action from areas where abatement action could be deferred. An assessment approach had been proposed and refined during a two-day workshop by consultants, administrators, and others with asbestos management experience (USEPA 1986a). Plans were being developed to field test the assessment method.

Plans for the two studies were reconsidered when, in October, 1986, the Asbestos Hazard Emergency Response Act (AHERA) (Public Law 99-160) was signed into law. AHERA introduced assessment and abatement concepts and terminology that were different in some major respects from the concepts and terminology that were about to be field tested. AHERA required EPA to promulgate regulations within one year, addressing inspections, abatement, and management of ACM in schools.

In addition to regulations pertaining to asbestos in schools, Section 213 of AHERA required EPA to report to Congress within one year on regulatory issues for public and commercial buildings. Specifically, the report to Congress was to:

- assess the extent to which asbestos-containing materials are present in public and commercial buildings;
- assess the condition of asbestos-containing materials in commercial buildings and the likelihood that persons occupying such buildings, including service and maintenance personnel, are, or may be, exposed to asbestos fibers;

- consider and report on whether public and commercial buildings should be subject to the same inspection and response action requirements that apply to school buildings;

- assess whether existing federal regulations adequately protect the general public, particularly abatement personnel, from exposure to asbestos during renovation and demolition of such buildings; and

- include recommendations that explicitly address whether there is a need to establish standards for, and regulate asbestos exposure in public and commercial buildings.

Section 213 of AHERA placed significant new demands on EPA to collect and analyze data relating to asbestos in buildings. Due to the short time frame to meet the AHERA requirements, EPA had to rely primarily on existing data for the Section 213 report to Congress. For example, to gain insight on the extent and condition of ACM in public and commercial buildings, additional analyses of data collected in a 1983-84 EPA survey of asbestos in buildings were conducted (Rogers 1987). In addition to using existing information, EPA conducted a field study which included air monitoring. The study was designed with three objectives:

- to determine if airborne asbestos levels are elevated in buildings that have ACM;

- to field test an assessment method developed to facilitate abatement decision making in the context of an asbestos management program; and

- to gather data to help EPA make recommendations to Congress on future regulation of public and commercial buildings (in order to meet the AHERA Section 213 requirements).

In order to satisfy these objectives, inspection, assessment, and air monitoring were conducted in three types of buildings: (1) buildings without ACM; (2) buildings with all or most of the ACM in good condition allowing for a limited number of areas of moderate damage; and (3) buildings which had at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM. These three building types are subsequently referred to as Categories 1, 2, and 3, respectively.

Severe resource and time constraints precluded doing a national survey of public and commercial buildings, and necessitated the identification of an appropriate subset of buildings. During 1987, when the study was being planned, the General Services Administration (GSA) was in the process of implementing a national asbestos management program in federally owned buildings. The population of GSA owned buildings provided an efficient laboratory for this study. GSA buildings had been inspected and the ACM had been identified and evaluated. Buildings were selected based on prior evaluation and identification with one of the building categories. Without this information, an expensive and time-consuming preliminary study involving a much larger number of buildings would have been required to identify buildings that contained asbestos. Also, building access was assured in GSA buildings, avoiding the access problems typically encountered in privately-owned buildings.

Based on GSA asbestos building records, 67 buildings distributed across five study regions were chosen for study and initially classified into the three building categories defined above. These buildings had been inspected for ACM previously by GSA. The buildings were reinspected, bulk samples collected and analyzed, and ACM condition rated in four or more sites per building by four inspectors. The bulk samples and assessment data that were collected by the field teams were used to field test the assessment method and to verify the initial classification of the building categories. Forty-nine buildings were chosen for air monitoring. Among the 49 buildings six had no ACM (Category 1), six had ACM primarily in good condition (Category 2), and 37 had at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM (Category 3). A total of 387 air samples were collected from the 49 buildings (an average of eight per building) including 48 samples of outdoor air (one per building with one exception where outdoor sampling was not possible).

Buildings initially classified as Category 1 (no ACM) or Category 2 (ACM primarily in good condition) were entirely reinspected by an experienced building inspector to confirm the classifications. During each of these inspections, bulk samples were collected and analyzed by polarized light microscopy (PLM). The ACM in buildings in Category 2 and Category 3 was evaluated by an assessment team consisting of four raters. Two "core" raters evaluated four or more sites in each Category 2 and 3 building in each of the five study regions. The other two raters were "local" (regional EPA, GSA, or local city government staff) and evaluated buildings in their own region only. With the exception of one study region, the raters attended a professional training course before the field work began. The rating data were used to confirm the classification of Category 2 and 3 buildings and to measure the consistency of the rating method.

Air monitoring was conducted in an average of seven areas inside each building and one area outside. Half of the inside samples were collected near the most damaged ACM in each building, if damaged material was present. ("Most damaged" could mean ACM in good or moderately damaged condition if no significantly damaged ACM was found in the building.) The remaining samples were collected in public areas. Each sample was taken over a two-day period, eight hours per day, during periods of normal building activity. The samples were analyzed by transmission electron microscopy (TEM) using a direct filter preparation method to estimate the airborne asbestos structure concentrations within the buildings. Asbestos structures include asbestos fibers and asbestos bundles, clusters, and matrices.

A comprehensive quality assurance (QA) program governed all field data collection and laboratory analysis activities. A variety of standard QA samples were collected and analyzed. The results indicated a high level of precision and accuracy in the data.

Conclusions:

Objective (1): Determine if airborne asbestos structure levels are elevated in buildings that have asbestos-containing materials.

While the differences in airborne asbestos levels are small in absolute magnitude, the results of this study indicate a tendency for average airborne asbestos levels in buildings with ACM to be higher than average levels in buildings without ACM (comparing the medians of the building averages). Airborne asbestos concentrations in Category 1 buildings (no ACM) have the smallest median level; the median level in Category 2 buildings (all or most of the ACM in good condition allowing for a limited number of areas of moderate damage) is higher than the median level in Category 1; and the median level in Category 3 buildings (at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM) is highest. The air monitoring results are summarized in Table 1. The difference between Category 1 and Category 3 medians is statistically significant at the 0.02 level. The remaining comparisons among building categories are not statistically significant (each has p-values of 0.18 or greater).

The median of building averages in Category 3 buildings is higher than the median ambient outdoor level. The evidence for a significant difference is not strong, but is suggestive of a trend: the difference is statistically significant at the 0.09 level of significance (i.e, the p-value is 0.09). The other two building categories when compared to ambient outdoor levels suggest no difference (that is, they have p-values greater than 0.60). Estimates of indoor asbestos levels are more precise than estimates of outdoor levels because indoor levels are based on several samples per building. Outdoor levels are based on one

Table 1. Summary Statistics for Average Airborne Asbestos Structure Concentrations (s/cc)

Statistic	Outdoor	Category 1	ACM Category 2	 Category 3
Median	<0.00001	0.00010	0.00040	0.00058
Mean	0.00039	0.00099	0.00059	0.00073
Sample size	48 (sites)	6 (buildings)	6 (buildings)	37 (buildings)
Standard deviation	0.00096	0.00198	0.00052	0.00072

Notes:

1. The data points used in the calculation of each statistic are the average concentration within a building (for indoor samples) or the concentration outside each building (for outdoor samples).

2. The mean for Category 1 is heavily influenced by one sample in one building which produced an unexplained large s/cc value. The Category 1 mean, excluding this one value, is 0.00020 s/cc.

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sample per building. Thus, an observed difference between two building categories corresponds to a smaller p-value than the same observed difference between a building category and outdoors.

The buildings in this study were selected from three building categories in order to investigate relationships between building category and airborne asbestos levels. It is important to note that the method of selection does not allow formal, statistical projection of the total number of buildings which have characteristics measured in the study to the population of GSA buildings, federally owned buildings, or public and commercial buildings. However, since the buildings were selected without prior knowledge of airborne asbestos levels or without prior knowledge of any other variable measured in the study, the resulting relationships are suggestive of true relationships in buildings similar to those studied.

Objective (2): Field test an assessment method developed to facilitate abatement decision making in the context of an asbestos management program.

Using rater consistency as an evaluation criterion, the definitions of material condition, potential for disturbance, and air flow used in this study, show promise as assessment tools for use in the field. P-values less than 0.05 indicated that consistency among raters was greater than expected if ratings were applied at random. Two hundred fifty seven areas within 60 buildings in five study regions were assessed by a team of two core raters. In addition, in each of the five study regions a team of two local raters evaluated the buildings in their study region.

Assessment of material condition was the factor most consistently rated across the five study regions. Assessment of potential for disturbance was less consistent. Assessment of air flow showed the greatest level of variability. Trends observed in the data suggest that lack of consistency among raters can be attributed, in part, to imprecision in definitions and lack of training.

Objective (3): Gather data to help EPA make recommendations under AHERA to Congress on future regulation of public and commercial buildings (in order to meet the AHERA Section 213 requirements).

This objective was met indirectly by the total body of information collected in this study which was combined with information from a variety of sources and considered in the preparation of the AHERA Section 213 report to Congress. While the air monitoring data collected to satisfy this study's first objective are not necessarily representative of air levels in all public and commercial buildings, they provide information pertinent to exposure issues raised in AHERA Section 213. The conclusions regarding the second objective, assessment method evaluation, are pertinent to management programs in public and commercial buildings as well as the schools that are covered by the AHERA regulations. This information will be considered in the preparation of future guidance documents, training programs, and regulations for public and commercial buildings.

1.0 INTRODUCTION

1.1 BACKGROUND

This study, referred to as the Public Buildings Study, was designed and conducted during a period when information needs concerning asbestos in buildings were rapidly changing and expanding. Late in 1985, while administering the Asbestos School Hazard Abatement Act (ASHAA) (Public Law 98-377), EPA was asked to conduct an air monitoring study of asbestos levels in buildings. The request, submitted to the 99th Congress in a report by the House Committee on Appropriations (House Report 99-212), appropriated $500,000 for air monitoring studies when signed on November 25, 1985. These air monitoring studies were intended to provide data on asbestos exposure levels inside buildings with asbestos-containing materials (ACM) and ambient outdoor levels. In response to this request, EPA began planning an air monitoring study to be conducted in the latter part of 1986 and early 1987.

Simultaneously, EPA was engaged in the development of an assessment method for differentiating areas of ACM requiring immediate abatement action from areas where abatement action could be deferred. An assessment approach had been proposed and refined during a two-day workshop by consultants, administrators, and others with asbestos management experience (USEPA 1986a). Plans were being developed to field test the assessment method.

Plans for the two studies were reconsidered when, in October, 1986, the Asbestos Hazard Emergency Response Act (AHERA) (Public Law 99-160) was signed into law. AHERA introduced assessment and abatement concepts and terminology that were different in some major respects from the concepts and terminology that were about to be field tested. AHERA required EPA to promulgate regulations within one year, addressing inspections, abatement, and management of ACM in schools.

In addition to regulations pertaining to asbestos in schools, Section 213 of AHERA required EPA to report to Congress within one year on regulatory issues for public and commercial buildings. Specifically, the report to Congress was to:

- assess the extent to which asbestos-containing materials are present in public and commercial buildings;
- assess the condition of asbestos-containing materials in commercial buildings and the likelihood that persons occupying such buildings, including service and maintenance personnel, are, or may be, exposed to asbestos fibers;

- consider and report on whether public and commercial buildings should be subject to the same inspection and response action requirements that apply to school buildings;
- assess whether existing federal regulations adequately protect the general public, particularly abatement personnel, from exposure to asbestos during renovation and demolition of such buildings; and
- include recommendations that explicitly address whether there is a need to establish standards for, and regulate asbestos exposure in public and commercial buildings.

Section 213 of AHERA placed significant new demands on EPA to collect and analyze data relating to asbestos in buildings. Due to the short time frame to meet the AHERA requirements, EPA had to rely primarily on existing data for the Section 213 report to Congress. For example, to gain insight on the extent and condition of ACM in public and commercial buildings, additional analyses of data collected in a 1983-84 EPA survey of asbestos in buildings were conducted (Rogers 1987). In addition to using existing information, EPA conducted a field study which included air monitoring.

In order to meet the objectives of the public buildings study, which are formally stated and discussed in Section 1.2, inspection, assessment, and air monitoring were conducted in three categories of buildings: (1) buildings without ACM; (2) buildings with all or most of the ACM in good condition allowing for a limited number of areas of moderate damage; and (3) buildings which had at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM. A number of practical problems prevented EPA from constructing a comprehensive list of all public and commercial buildings from which to draw a national probability sample of buildings with the desired characteristics. To develop such a listing would have required more resources than were available for this study and the additional time necessary would have precluded the collection of information in time to consider it in the preparation of the AHERA Section 213 report, due to Congress in October 1987.

The General Services Administration (GSA) was in the process of implementing a national asbestos management program in federally owned buildings. The population of GSA owned buildings provided an efficient laboratory for this study. GSA buildings had been inspected and the ACM had been identified and evaluated. Buildings were selected based on prior evaluation and identification with one of the building categories. Without this information, an expensive and time-consuming preliminary study involving a much larger number of buildings would have been required to identify buildings that contained asbestos. Also, building access was assured in GSA buildings, avoiding the access problems typically encountered in privately-owned buildings. Details concerning the study design, including the method used to select buildings and data collection techniques, are presented in subsequent sections of this report.

1.2 OBJECTIVES

The Public Buildings Study had three objectives:

- to determine if airborne asbestos levels are elevated in buildings that have ACM;
- to field test an assessment method developed to facilitate abatement decision making in the context of an asbestos management program; and
- to gather data to help EPA make recommendations to Congress on future regulation of public and commercial buildings (in order to meet the AHERA Section 213 requirements).

A brief discussion of each objective follows.

Objective (1): Determine if airborne asbestos levels are elevated in buildings that have asbestos-containing materials.

GSA buildings were selected from three categories of buildings for air monitoring. Indoor and ambient outdoor air was monitored for asbestos at each building. Airborne asbestos levels measured in buildings with ACM were compared to levels in buildings without ACM. Indoor and ambient outdoor levels were also compared. These comparisons were used to determine if airborne asbestos levels in buildings with ACM are elevated. The buildings in this study were selected from three building categories in order to investigate relationships between building category and airborne asbestos levels. It is important to note that the method of selection does not allow formal, statistical projection of the total number of buildings which have characteristics measured in the study to the population of GSA buildings, federally owned buildings, or public and commercial buildings. However, since the buildings were selected without prior knowledge of airborne asbestos levels or without prior knowledge of any other variable measured in the study, the resulting relationships are suggestive of true relationships in buildings similar to those studied.

Objective (2): Field test an assessment method developed to facilitate abatement decision making in the context of an asbestos management program.

The assessment factors described in the November 7, 1986 draft of "Guidance for Assessing and Managing Exposure to Asbestos in Buildings" (USEPA, 1986a) were tested in the field. Consistency among different raters assessing the same sites was evaluated. The buildings and areas in buildings used in the study were selected to ensure that a range of ACM materials and conditions would be rated. The rating data collected to test and analyze consistency among raters, therefore, do not provide information about the characteristics of ACM that can be projected to the population of all federal buildings. The results, however, can be used to suggest ways in which consistency among raters can be improved.

Objective (3): Gather data to help EPA make recommendations under AHERA to Congress on future regulation of public and commercial buildings (in order to meet the AHERA Section 213 requirements).

Section 213 of AHERA requires that information be developed to address the five specific issues previously listed. Most of the information required for Section 213 has been developed in other studies. Information collected in the current study may be used to supplement these other sources, as appropriate.

1.3 ORGANIZATION OF REPORT

The report consists of eight sections. This section, Section 1, includes the background and objectives, which provide an introduction to the study. Conclusions are summarized in Section 2. Quality assurance, the study design, and the field methods are presented in Sections 3, 4, and 5, respectively. The sample analysis methods, statistical analysis, and results are presented in Sections 6, 7 and 8. Section 6 addresses the field test of the assessment factors, Section 7 addresses bulk sampling, and Section 8 is the air monitoring portion of the study.

2.0 CONCLUSIONS

The study conclusions are organized and discussed in relationship to the three study objectives. During 1987, when the study was conducted, GSA was in the process of implementing an asbestos management program in buildings. The impact of the management program, if any, is not addressed in these conclusions. Results of statistical tests are indicated by "p-values." A p-value is the probability of obtaining a result as extreme or more extreme than the result observed under the null hypothesis of no difference or relationship between the factors being studied. A small p-value indicates that the magnitude of the observed result is unlikely under the null hypothesis, and therefore lends support to the alternative hypothesis, namely that the difference or relationship is real. Detailed presentations of the results supporting the conclusions are found in Sections 6, 7, and 8.

Objective (1): Determine if airborne asbestos structure levels are elevated in buildings that have asbestos-containing materials.

While the differences in airborne asbestos levels are small in absolute magnitude, the results of this study indicate a tendency for average airborne asbestos levels in buildings with ACM to be higher than average levels in buildings without ACM (comparing the medians of the building averages). Airborne asbestos concentrations in Category 1 buildings (no ACM) have the smallest median level; the median level in Category 2 buildings (all or most of the ACM in good condition allowing for a limited number of areas of moderate damage) is higher than the median level in Category 1; and the median level in Category 3 buildings (at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM) is highest. The air monitoring results are presented in Figure 2-1 and summary statistics are given in Table 2-1. The difference between Category 1 and Category 3 medians is statistically significant at the 0.02 level. The remaining comparisons among building categories are not statistically significant (each has p-values of 0.18 or greater).

The median of building averages in Category 3 buildings is higher than the median ambient outdoor level. The evidence for a significant difference is not strong, but is suggestive of a trend: the difference is statistically significant at the 0.09 level of significance (i.e., the p-value is 0.09). The other two building categories when compared to ambient outdoor levels suggest no difference (that is, they have p-values greater than 0.60). Estimates of indoor asbestos levels are more precise than estimates of outdoor levels because indoor levels are based on several samples per building. Outdoor levels are based on one

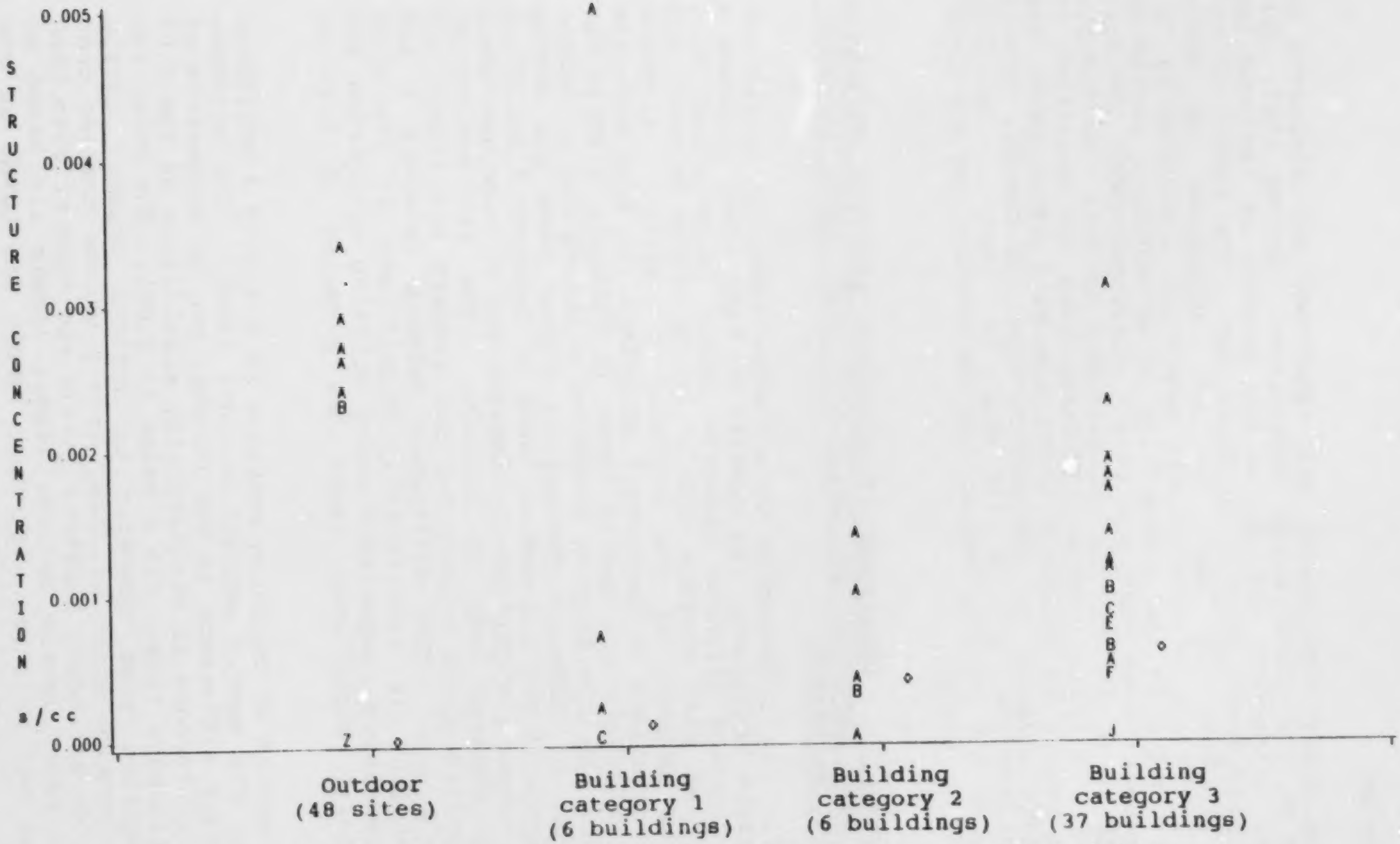

Figure 2-1. Scatter plots* and medians of the average airborne asbestos structure concentrations for each building category and outdoors.

*The data points for each scatter plot are the average concentration within a building (for indoor samples) or the concentration outside each building (for outdoor samples). A=1 data point, B=2 data points, ..., J=10 data points, and Z=41 data points. The diamond represents the median of the data points in each scatter plot.

Table 2-1. Summary Statistics for Average Airborne Asbestos Structure Concentrations (s/cc)

Statistic	Outdoor	ACM Category 1	 Category 2	 Category 3
Median	<0.00001	0.00010	0.00040	0.00058
Mean	0.00039	0.00099	0.00059	0.00073
Sample size	48 (sites)	6 (buildings)	6 (buildings)	37 (buildings)
Standard deviation	0.00096	0.00198	0.00052	0.00072

Notes:

1. The data points used in the calculation of each statistic are the average concentration within a building (for indoor samples) or the concentration outside each building (for outdoor samples).

2. The mean for Category 1 is heavily influenced by one sample in one building which produced an unexplained large s/cc value. The Category 1 mean, excluding this one value, is 0.00020 s/cc.

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sample per building. Thus, an observed difference between two building categories corresponds to a smaller p-value than the same observed difference between a building category and outdoors.

The buildings in this study were selected from three building categories in order to investigate relationships between building category and airborne asbestos levels. It is important to note that the method of selection does not allow formal, statistical projection of the total number of buildings which have characteristics measured in the study to the population of GSA buildings, federally owned buildings, or public and commercial buildings. However, since the buildings were selected without prior knowledge of airborne asbestos levels or without prior knowledge of any other variable measured in the study, the resulting relationships are suggestive of true relationships in buildings similar to those studied.

Objective (2): Field test an assessment method developed to facilitate abatement decision making in the context of an asbestos management program.

Using rater consistency as an evaluation criterion, the definitions of material condition, potential for disturbance, and air flow used in this study, show promise as assessment tools for use in the field. P-values less than 0.05 indicated that consistency among raters was greater than expected if ratings were applied at random. Two hundred fifty-seven areas within 60 buildings in five study regions were assessed by a team of two core raters. In addition, in each of the five study regions a team of two local raters evaluated the buildings in their study region. The study regions are numbered in the order in which they were sampled, (i.e., Study Regions 1 to 5). This numbering scheme is not related to the regional classification used by either GSA or EPA.

Figure 2-2 shows that assessment of material condition was the factor most consistently rated across the five study regions. Assessment of potential for disturbance was less consistent. Assessment of air flow showed the greatest level of variability. Trends observed in Figures 2-3, 2-4 and 2-5 suggest that lack of consistency among raters can be attributed, in part, to imprecision in definitions and lack of training, both of which can be remedied. This conclusion is based on the following results:

- There is greater consistency among raters when assessing condition than when assessing potential for disturbance. In this study, condition was defined in quantitative terms (e.g., terms such as greater than 10% damage) whereas the definitions for disturbance were more qualitative.

- Consistency in air flow ratings varies from study region to study region, with low consistency in some study regions and high consistency in others. The present two-part scale does not distinguish significant air flow from very slight air flow. A three-part scale (high, moderate, and low/none) for air flow may increase consistency.

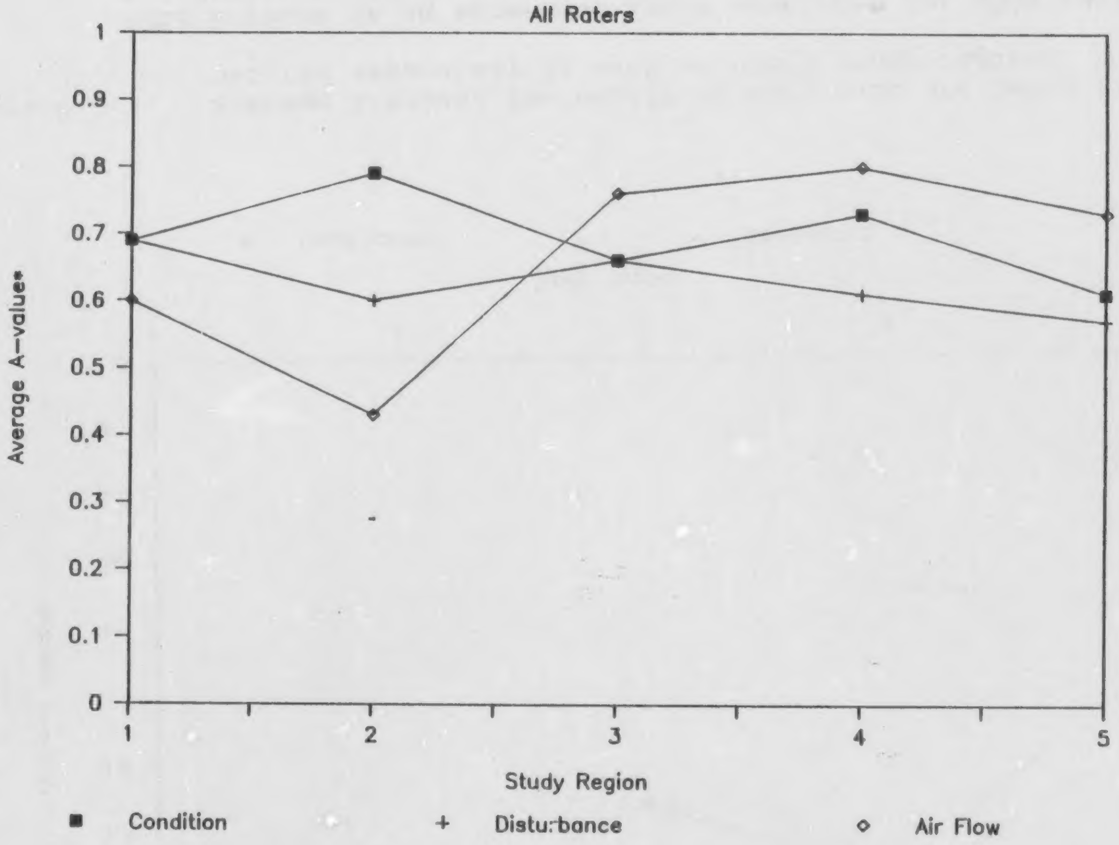

Figure 2-2. The average agreement index, also called the average A-value, for condition, disturbance, and air flow in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement. The basis for A-values is explained in Section 6.

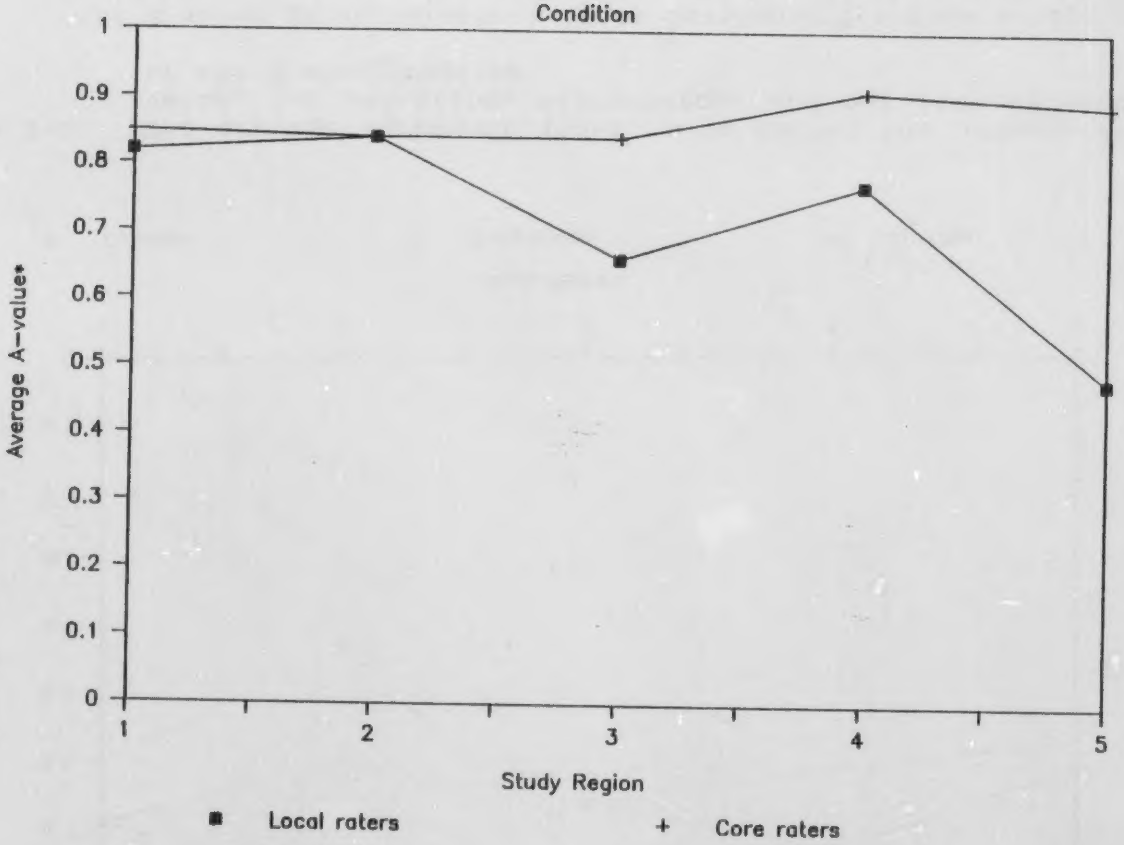

Figure 2-3. **Average A-values for condition with core and local raters plotted separately in each of the 5 study regions.**

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement. The basis for A-values is explained in Section 6.

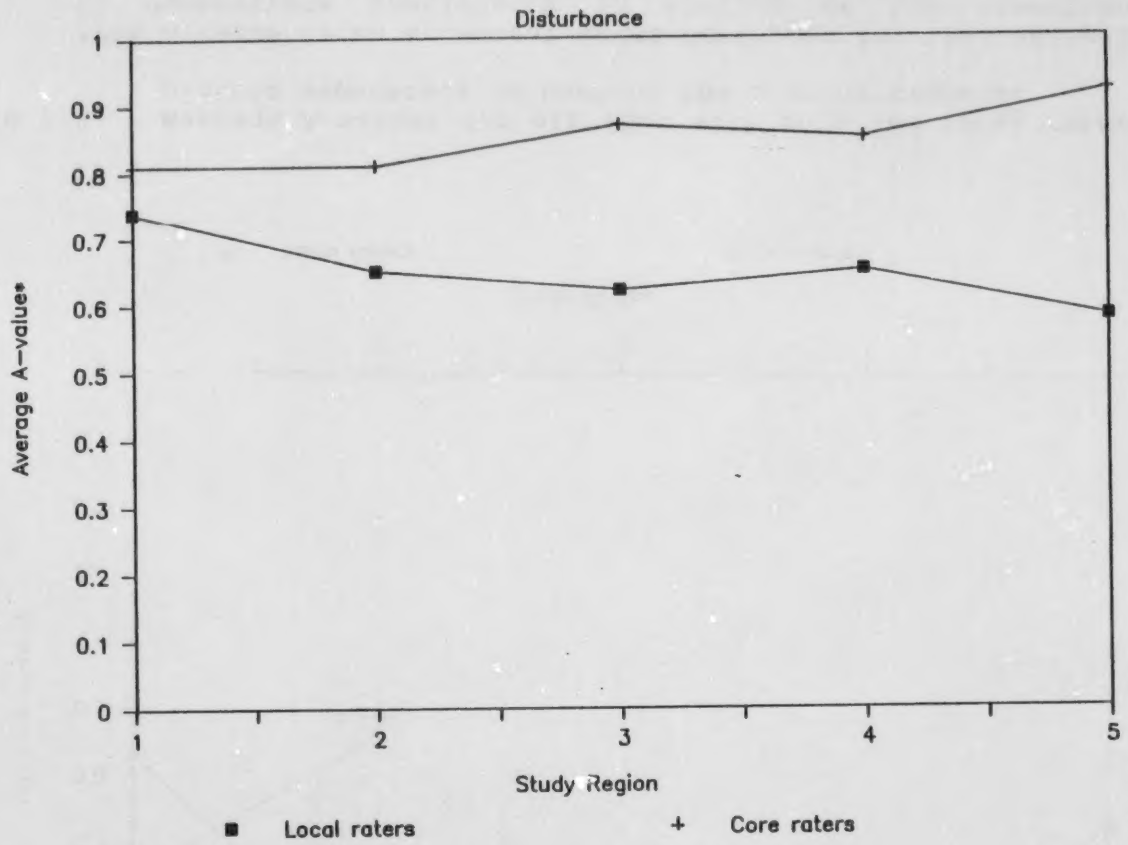

Figure 2-4. Average A-values for disturbance with core and local raters plotted separately in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement. The basis for A-values is explained in Section 6.

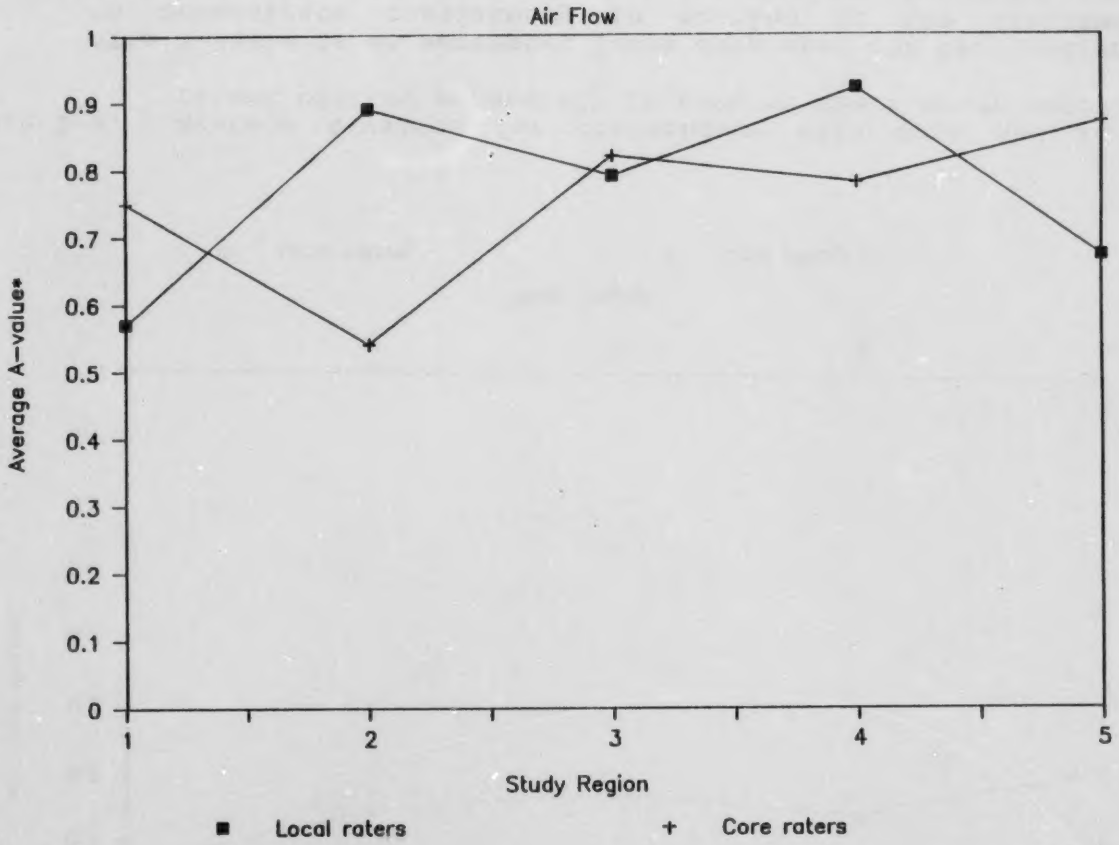

Figure 2-5. Average A-values for air flow with core and local raters plotted separately in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement. The basis for A-values is explained in Section 6.

- Consistency between the core raters is greater than consistency between the local raters. The core raters had more experience in applying the assessment method.

- Region 5 local raters, who did not attend the training, showed the least consistency in assessing condition and potential for disturbance.

Objective (3): Gather data to help EPA make recommendations under AHERA to Congress on future regulation of public and commercial buildings (in order to meet the AHERA Section 213 requirements).

This objective was met indirectly by the total body of information collected in this study which was combined with information from a variety of sources and considered in the preparation of the AHERA Section 213 report to Congress. While the air monitoring data collected to satisfy this study's first objective are not necessarily representative of air levels in all public and commercial buildings, they provide information pertinent to exposure issues raised in AHERA Section 213.

The conclusions regarding the second objective, assessment factor evaluation, are pertinent to management programs in public and commercial buildings as well as the schools that are covered by the AHERA regulations. This information will be considered in the preparation of future guidance documents, training programs, and regulations for public and commercial buildings.

3.0 QUALITY ASSURANCE

3.1 INTRODUCTION

This section presents an overview of quality assurance (QA) procedures followed in this study and the results of those procedures. The details on the statistical analysis of QA data are presented in Sections 7 and 8. Guidelines for the QA of the data collected in this study were set forth in a comprehensive Quality Assurance Plan (Hatfield et al. 1987). All procedures were employed, and unavoidable deviations were documented.

Two types of measurements were collected in the field: bulk samples and air samples. Bulk samples were analyzed with polarized light microscopy (PLM) to determine the percentage of asbestos present. For the purposes of this study, only the presence (">1%") or absence ("none detected" or "trace") of asbestos from a given site was utilized. Air samples were analyzed with transmission electron microscopy (TEM) direct filter preparation to estimate the asbestos structure concentration for each site. QA procedures were performed for all aspects of data collection and analysis.

Chain-of-custody procedures were implemented for all samples collected during the project. Field custody procedures were used to document the location and handling of each sample from the time of collection until received by the analytical laboratory. At this point, internal laboratory records were used to document the chain-of-custody of each sample through to its final disposition.

3.2 BULK SAMPLE AND POLARIZED LIGHT MICROSCOPY QUALITY ASSURANCE

As specified in the QA plan, various types of quality control (QC) samples were collected and analyzed to determine the accuracy and precision of asbestos content estimates. Included were: side-by-side duplicates, and external (referee laboratory) analyses and replicate analyses. A side-by-side duplicate is a sample collected in the immediate area of the original sample but handled separately. The degree of agreement of the analyses of the original sample with its duplicate indicates the level of precision in the sample collection and field handling procedures. An external analysis is one in which the sample is analyzed a second time by another analytical laboratory. This type of analysis is performed as a QC check on the performance of the method by the primary laboratory. The degree of agreement of the original analysis with the external analysis indicates the consistency of the method performance. A replicate analysis is one in which the same sample is analyzed twice by the same analytical laboratory. The degree of agreement of the two analyses indicates the level of precision in the laboratory analysis procedures.

All three of the QC procedures described above were used for the analyses of the bulk samples in this study. The results of these QC analyses indicated a very high level of precision and accuracy in the bulk sample collection and PLM analyses.

3.2.1 Side-by-Side Duplicates

A total of 279 bulk samples were collected by the building inspector and rating team in the field and analyzed for asbestos content. Of these 279 samples, 20 were collected in the field as side-by-side duplicates (20/259 = 8%). With respect to presence or absence of asbestos, all 20 of the side-by-side duplicates agreed with their original sample (100% agreement).

3.2.2 External Analyses

From the 279 bulk samples, 31 were randomly chosen for external analysis by a second laboratory (31/279 = 11%). With respect to the presence or absence of asbestos, 30 of the 31 externals agreed with their original samples (30/31 = 97% agreement). The one disagreement did not result in the misclassification of the building category as verified by additional bulk samples collected at that area by the rating team.

The primary analytical laboratory also performed its own QC checks. The laboratory participated in the EPA Asbestos Bulk Sample Analysis Quality Assurance Program. Sixteen bulk samples (for which the "true" percentage of asbestos is known) were submitted as blind QC samples along with the field samples. With respect to the presence or absence of asbestos, all 16 of these results agreed with the original determination (100% agreement).

3.2.3 Replicate Analyses

The analytical laboratory randomly chose 33 of the 279 field-collected samples and resubmitted them for replicate bulk sample analysis (33/279 = 12%). With respect to the presence or absence of asbestos, 32 of the 33 replicates agreed with the original result (32/33 = 97% agreement). The one disagreement did not result in the misclassification of the building category because that building's classification was based on another area where several samples were used to verify the presence of asbestos.

3.3 AIR SAMPLE AND TRANSMISSION ELECTRON MICROSCOPY QUALITY ASSURANCE

The QA procedures used to ensure the accuracy and precision of the air sample collection and TEM analyses included the collection of production lot and field blanks, field audits, laboratory audits, replicate and external analyses, and a study to further evaluate the results obtained by the TEM method.

Production lot blanks are filters chosen prior to the start of field work. They are analyzed by the analytical laboratory to check for filter contamination. Field blanks are filters taken into the field and handled in the same manner as exposed air sample filters. Their purpose is to check for contamination which might occur in the field but not as a result of air sampling. Field audits determine whether the field team is following set procedures. Laboratory audits determine the same for the analytical laboratory personnel. Replicate and external analyses serve the same purpose as discussed above for PLM analyses.

3.3.1 Production Lot Blanks

Blank filters from prescreened production lots were randomly selected three times during the project: at the beginning of field activities, in the middle, and near completion. Each time, two filter cassettes were randomly selected from a previously unopened box of 50 filters. A total of 26 production lot blanks were selected in this way for analysis. The analysis of the production lot blanks indicated that there was not a problem with background filter contamination.

3.3.2 Field Blanks

During the pump set-up, preloaded filter cassettes were selected as field blanks. These filters were labeled and handled in an identical manner as were the sample filters, except that they were not attached to the sampling pump. The filters were capped during active sampling periods and open faced during the non-run hours when the actual sample cassettes were also open faced. Field blanks were collected in 30 of the buildings sampled. The purpose of the field blanks was to measure contamination which might occur during periods when the pumps were not running.

Of the 30 field blanks collected, 19 were selected for analysis. If a high level of contamination was found from the analysis results of the 19 blanks, the remaining 11 blanks would have been analyzed. The 19 blanks that were analyzed were chosen at random from the 30 blanks collected. No structures were detected in 18 of the 19 field blanks that were analyzed. A single fiber was counted on the remaining blank. This level of blank contamination corresponds to an airborne asbestos structure concentration of 0.00015 s/cc when 5,000 L of air is collected, a very low level of contamination. Thus, it was not necessary to analyze the remaining blanks.

3.3.3 Field Audits

Five field audits were conducted by an independent field auditor, one audit in each of the study regions. The field auditor accompanied the field crew during pump set-up in several buildings per study region. He checked to be sure that the field crew was following the guidelines set forth in the Quality Assurance Plan (Hatfield et al. 1987), and documented any violations in procedures so they could be corrected. For example, an air hose on one pump was found to be punctured. This was noted and immediately corrected. The field auditor also measured 216 flow rates in pumps in these buildings. This was done in order to estimate the relative accuracy of the flow rates, defined as [(field value-audit value)/(audit value)] x 100. The percentage of flow rates within ± 20% relative accuracy was 99%.

3.3.4 Laboratory Audits

To ensure the accuracy of the air sample analyses using TEM, two laboratory audits were performed. An independent laboratory auditor visited the TEM analytical laboratory to verify that all procedures specified in the Quality Assurance Plan (Hatfield et al. 1987) were followed. He audited the analytical laboratory twice, at the beginning of the analyses and at the end.

3.3.5 Replicate and External Analyses

Twenty air samples to be used for replicate and external TEM analyses were chosen at random from a total of 387 air samples (20/387 = 5%). These samples were recoded and submitted to the original analytical laboratory for replicate analyses. They were then sent to a second TEM laboratory for external analyses. Thus, for these 20 samples, 3 measurements were collected for each sample: the original, the replicate, and the external.

Very few asbestos structures were counted in any of the original, replicate, or external analyses. No asbestos structures were detected on 13 of the 20 samples (65%). A single structure was detected by one or more of the three analyses on the remaining seven samples. Statistical analysis (Section 8.3.6) of these data indicated that there is no evidence of inconsistency between the original, replicate, and external analyses.

3.3.6 Examination of Additional Grid Openings

In most of the original 387 TEM analyses, 10 grid openings were counted per sample filter to estimate the number of asbestos structures on each filter. These results were used to compute structure concentrations. To determine whether 10 grid openings per sample provided a sufficiently precise estimate of the number of structures on the filter, 40 additional grid openings were counted on 16 randomly-selected air samples, for a total of 50 grid openings per filter. Statistical analysis (Section 8.3.7) indicated that, in general, examination of 10 grid openings is sufficient.

4.0 STUDY DESIGN

The objectives of the Public Buildings Study, which are formally stated and discussed in Section 1.2, call for inspection and air monitoring in three types of buildings: (1) buildings without ACM; (2) buildings with all or most of the ACM in good condition (allowing for a limited number of areas of moderate damage); and (3) buildings with at least one area of significantly damaged ACM or numerous areas of moderately damaged ACM. These are referred to subsequently as Categories 1, 2, and 3, respectively. The objectives focus on relationships between building categories and airborne asbestos levels and ratings of ACM characteristics in different types of buildings.

Buildings were selected for the study from the population of federally owned buildings in five geographically dispersed regions of the United States (two cities on the east coast, one midwestern city, one western city, and a west coast region consisting of two cities). In this report the study regions are identified as Regions 1 to 5 according to the order in which they were sampled. This numbering scheme is not related to the regional classification used by either the General Services Administration (GSA) or EPA.

A target quota of 20 buildings was specified for evaluation in each study region: four buildings in Category 1; four buildings in Category 2; and 12 buildings in Category 3. The initial classification of these buildings into categories was based on inspection and evaluation information available from GSA records. The classification of each building was to be confirmed by the project team, and ten buildings (two in Category 1, two in Category 2, and six in Category 3) were to be selected in each study region for the air monitoring portion of the study.

By pooling data across the study regions, estimates for Category 3 would be based on measurements in 30 buildings (i.e., five study regions, six buildings per study region). Estimates for the other categories were to be based on measurements in 10 buildings (i.e., five study regions, two buildings per study region). When buildings are selected randomly and the coefficient of variation of individual measurements is between 1 and 1.25, a range observed in previous studies, the likelihood of detecting a five-fold difference between Category 3 and one of the other categories using Student's t-test with a significance level of 0.05 is at least 0.90 (i.e., the statistical power is at least 0.90). Relatively low airborne asbestos levels were anticipated in Categories 1 and 2 (i.e., buildings with no ACM or buildings with ACM primarily in good condition), and therefore, sample sizes sufficient to detect a five-fold differential were considered adequate.

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The study was intended to investigate two relationships: (i) the relationship between airborne asbestos levels and building category as defined previously; and (ii) the relationship between assessments conducted by different raters. It is important to determine if these relationships can be used to differentiate among extremes -- i.e., damaged ACM and ACM in good condition, or damaged ACM and no ACM. Therefore, buildings with these conditions must be included in the study regardless of how frequently or infrequently these conditions occur in the population of all buildings.

The population of GSA owned buildings provided an efficient laboratory for this study. GSA buildings had been inspected and the ACM had been identified and evaluated. Buildings were selected based on prior evaluation and identification with one of the building categories. Without this information, an expensive and time-consuming preliminary study involving a much larger number of buildings would have been required to identify buildings that contained asbestos. Also, building access was assured in GSA buildings, avoiding the access problems typically encountered in privately-owned buildings.

By selecting buildings in the manner described, the results regarding the relationships studied apply, from a formal statistical perspective, only to the buildings in the study. The approach used to select the buildings, however, is similar to many experimental studies where the experimental units selected satisfy predetermined specified criteria. Under these circumstances, projecting the total number of buildings which have characteristics measured in the study to an appropriate target population is not possible. However, since the buildings were selected without prior knowledge of airborne asbestos levels or without prior knowledge of any other variable that was measured and analyzed in the study, the resulting relationships are suggestive of true relationships in buildings similar to those studied. [In concept, the study circumstances are typical of "analytical" studies, which are differentiated from "enumerative" studies by Deming (1950).]

As discussed in detail in Section 6, differences in airborne asbestos levels among building categories and outdoors are indicated by plots and tables of summary statistics. The measured airborne asbestos levels, and consequently the statistics calculated from them, are subject to various sources of statistical error including air sampling and analytical error. A statistical test was applied to provide a quantitative measure of the strength of evidence associated with the observed differences (i.e., probabilities that the observed differences may have occurred only by chance were estimated).

For planning purposes, specifically the determination of sample size discussed above, airborne asbestos levels were assumed to follow a lognormal distribution and to be amenable to standard analysis of variance techniques used in previous studies (USEPA 1985b, 1986b; Tuckfield et al. 1987). Once the data were collected it was apparent that standard methods of analysis were not appropriate for this study because of the large number of zero observations. Therefore a permutation (also referred to as randomization) approach was used. The permutation test, which is based on the null hypothesis that all measured levels are independent observations from the same underlying statistical distribution, is consistent with the objectives and design of the study. Buildings were selected according to condition of ACM and without any knowledge of airborne asbestos levels. Therefore, in the absence of any relationship between condition and airborne asbestos levels, the measured values will be equivalent observations from a single distribution. To compare building categories, a "p-value," the level of significance, is estimated for each comparison. The p-value is the probability of obtaining a difference as great or greater than the difference observed under the hypothesis that no true difference exists. A small p-value indicates that the magnitude of the observed difference is unlikely under the hypothesis of no true difference, and therefore lends support to the alternative hypothesis, namely that the difference is real.

5.0 BUILDING SELECTION, INSPECTION AND ASSESSMENT FIELD METHODS

Sixty-seven buildings were selected for this study from a population of several thousand GSA buildings. Selection was based on GSA's asbestos building records. The assessment factors were tested in 60 of the buildings. Forty-nine buildings were selected from the original 67 for air monitoring. This section describes the field methods used to select and categorize the buildings by asbestos condition. It also describes the procedures used to test the assessment factors and to collect information to select the air monitoring sites. An overview of these methods is provided in Figure 5-1.

5.1 BUILDING SELECTION

Initial selection of buildings was achieved by reviewing the existing asbestos building records maintained by GSA in each of the five study regions. Buildings were chosen based upon the following criteria:

- Each building must be GSA-owned to ensure easy access.
- Each building must contain occupied office space (e.g., storage sheds were eliminated).
- Each building must have adequate asbestos building records indicating whether or not an assessment had been performed and whether or not ACM was present. Buildings with information on condition of the ACM were preferred.
- Buildings with surfacing ACM were preferred.
- All buildings within a given study region must be within a small enough area to facilitate sampling logistics. The exception to this was Study Region 4, which consisted of 2 cities, each sampled separately but counted as one study region.
- Buildings were excluded if more than a 3-day security clearance was required for the field personnel prior to gaining entry.

Information on each building was collected using the forms shown in Figures 5-2 and 5-3. Selected portions of the asbestos records for each building were photocopied.

Only 67 buildings were found to satisfy the above criteria. Therefore, the target quota of 20 buildings per study region could not be obtained. However, there were sufficient

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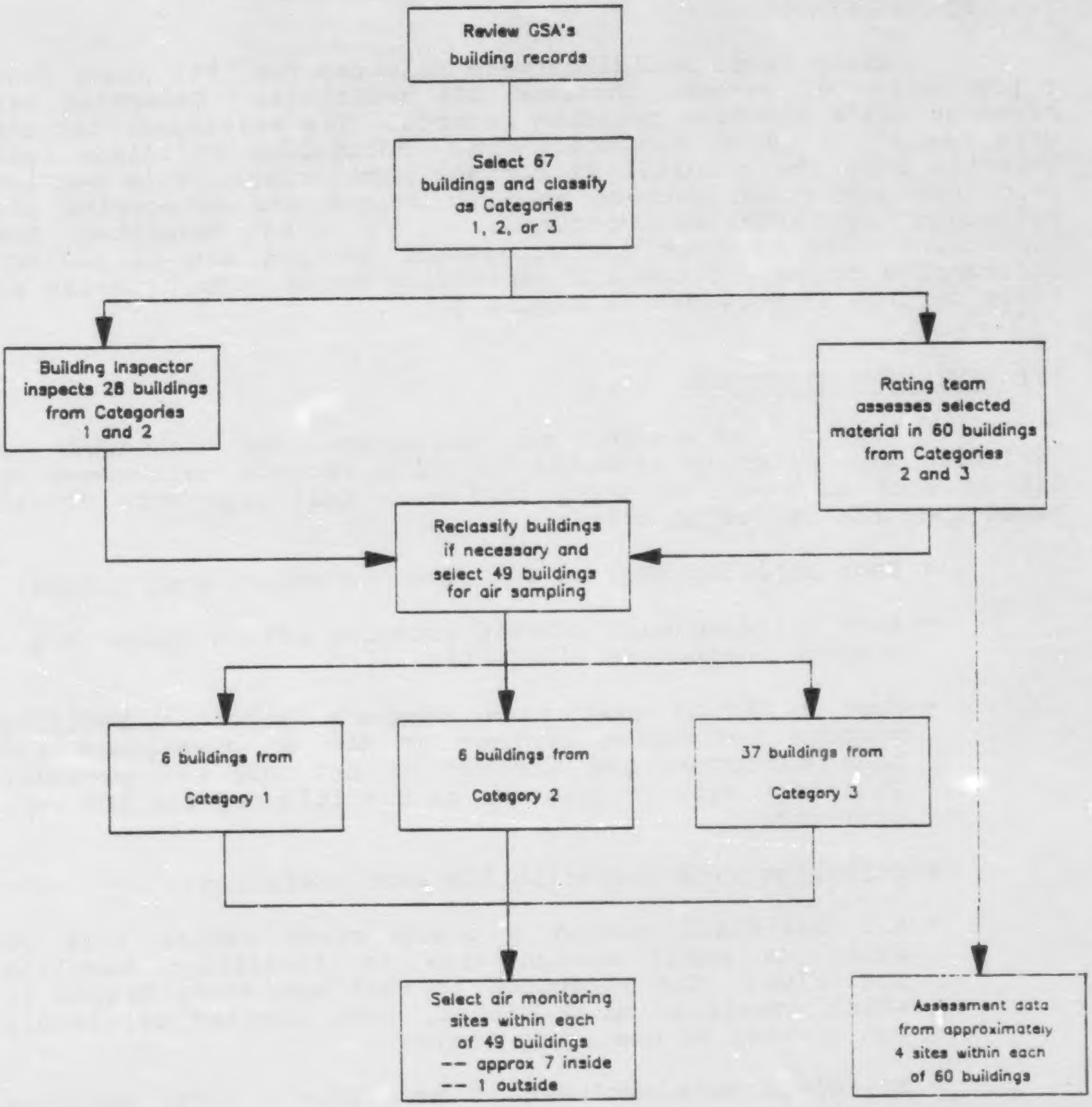

Review GSA's building records
Select 67 buildings and classify as Categories 1, 2, or 3
Building inspector inspects 28 buildings from Categories 1 and 2
Rating team assesses selected material in 60 buildings from Categories 2 and 3
Reclassify buildings if necessary and select 49 buildings for air sampling
6 buildings from Category 1
6 buildings from Category 2
37 buildings from Category 3
Select air monitoring sites within each of 49 buildings
-- approx 7 inside
-- 1 outside
Assessment data from approximately 4 sites within each of 60 buildings

Figure 5-1. Overview of field methods.

U.S. EPA Study of Airborne Asbestos Levels in Buildings

Initial Building Survey - Overall Building

Identification and Location

Building ID ______________

Building Name ____

Address ____

City/State/Zip ____

Contact person ______________________ Phone __________

Eligibility Verification

	Yes	No		Yes	No
GSA owned?	____	____	Bldg type okay?	____	____
GSA inspected?	____	____	Within geog. area?	____	____
If yes, date? __________					

Building and ACM Information

Group letter ____________

Assessment number ______

Exposure index __________

Asbestos-containing surfacing material present?

____Yes ____No ____Don't know

If yes, condition?

____

Asbestos-containing TSI present? _____Yes _____No _____Don't know

If yes, condition? ______________________________________

Number of ACM areas identified ___________

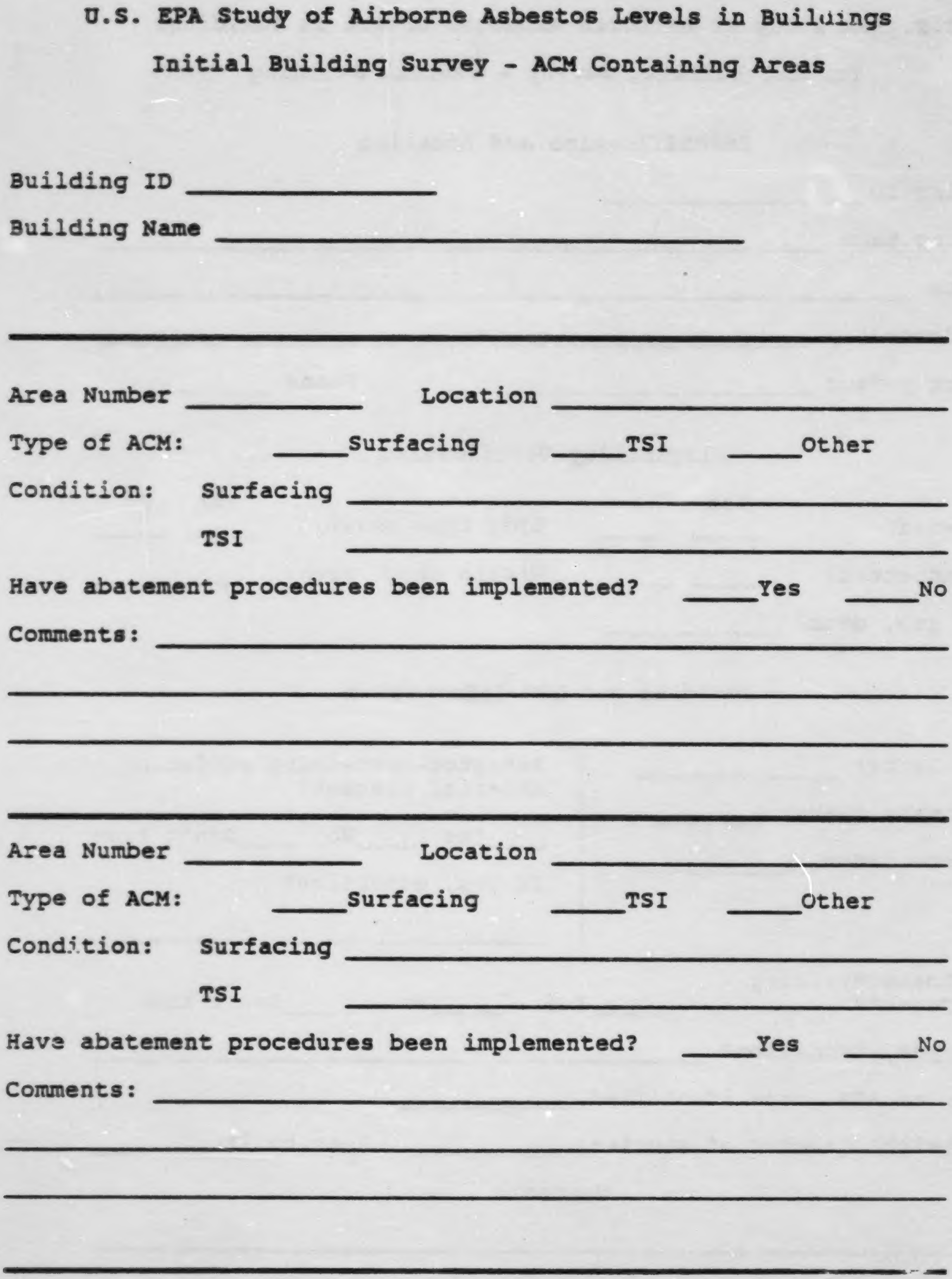
Bldg height (number of stories) _________ Year built _______

Comments

____

____

Figure 5-2. Form used while at GSA regional offices to collect information about the ACM in GSA buildings.



U.S. EPA Study of Airborne Asbestos Levels in Buildings

Initial Building Survey - ACM Containing Areas

Building ID ________________

Building Name __________________________________

Area Number ___________ Location ______________________

Type of ACM: _____Surfacing _____TSI _____Other

Condition: Surfacing ______________________________

TSI ______________________________

Have abatement procedures been implemented? _____Yes _____No

Comments: ____

____

____

Area Number ___________ Location ______________________

Type of ACM: _____Surfacing _____TSI _____Other

Condition: Surfacing ______________________________

TSI ______________________________

Have abatement procedures been implemented? _____Yes _____No

Comments: ____

____

____

Figure 5-3. Form used while at GSA regional offices to collect information about the ACM within specific areas in GSA buildings.

buildings to allow air sampling in 10 buildings per study region as planned. The breakdown of the number of buildings selected in each study region is as follows: Study Region 1 -- 17 buildings, Study Region 2 -- 10 buildings, Study Region 3 -- 11 buildings, Study Region 4 -- 13 buildings, and Study Region 5 -- 16 buildings.

Based on GSA's building records, each building was initially classified as Category 1, Category 2, or Category 3. Buildings which contained ACM, but had little or no information on the condition of the material were placed in Category 2. Based on subsequent field work performed in this study the classification of buildings into each category was confirmed prior to air monitoring. These results are discussed in Section 7.

5.2 BUILDING INSPECTION

In order to verify the classification of the Category 1 and Category 2 buildings, a qualified, independent building inspector inspected the buildings which were initially placed in these categories. The verification of the classification of buildings in Category 3 was accomplished by the assessment team.

In each Category 1 building, the building inspector performed a one-day inspection and collected bulk samples from any areas containing friable surfacing material and thermal systems insulation (TSI). In each Category 2 building, the inspector bulk sampled any friable surfacing material and TSI in areas that were indicated in the GSA building records as containing damaged ACM. He also searched for and sampled any other friable material he determined to be in worse condition. Building inspection was performed in each study region during the weeks of: Study Region 1 -- March 16, Study Region 2 -- March 23, Study Region 3 -- April 6, Study Region 4 -- April 20, and Study Region 5 -- May 4.

Bulk sampling was performed following the random sampling procedures described in USEPA (1985a). In addition, convenience samples were collected in the following circumstances:

- Pipe wrap in fan/boiler room;
- Limited access to sprayed-on material due to piping, ductwork, etc.; and
- Specific requests by the building escort or management not to collect more than one sample per site.

Undamaged TSI, except for exposed material, was not sampled since this would violate GSA's asbestos management program guidelines. Only friable surfacing materials and TSI were sampled (e.g., ceiling and floor tiles were not sampled). Detailed notes of the sampled areas, including the condition of the material, were maintained by the building inspector. A chain-of-custody form was completed for all samples (Figure 5-4). The bulk samples were mailed to the laboratory for analysis at the end of the inspection period in each study region.

Resulting from the building inspection is the final classification of each building in Category 1 and Category 2. These results are presented in Section 7.

5.3 ASSESSMENT

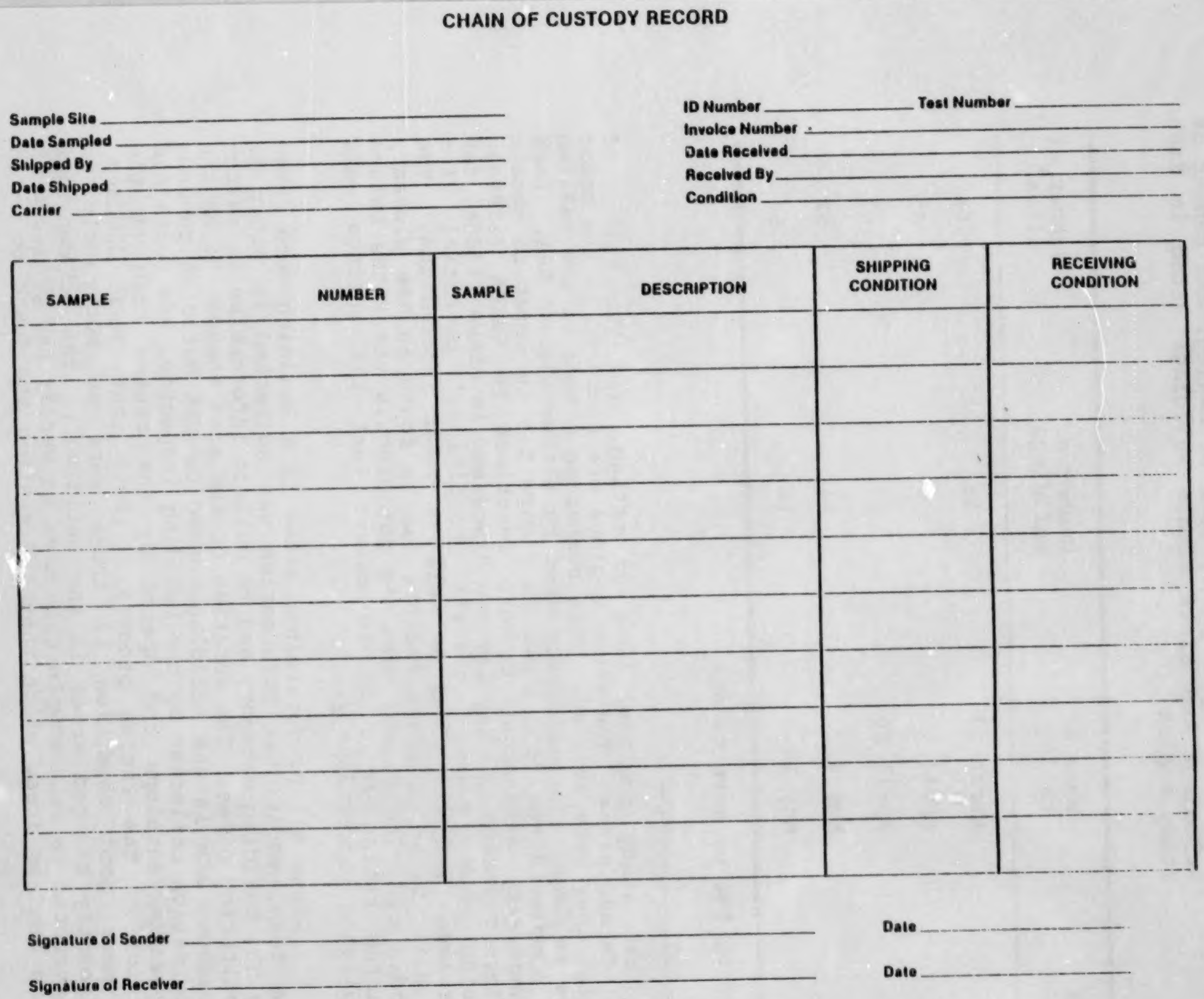
This section provides the methods for the field test of the assessment method for asbestos described in USEPA (1986a). The "field test" involved training individuals to apply the assessment factors and determining the degree of consistency among different individuals assessing the same material.

Another goal, which was achieved by using the individuals applying the assessment factors, was to further verify the condition of ACM in the buildings which were classified (based on GSA's asbestos building records) as Category 2 and Category 3. The assessment team, also called the rating team, collected bulk samples of damaged friable material to verify either the presence or absence of damaged ACM in these buildings. This information was then used to reclassify these buildings, when necessary, for air monitoring. The information was also used in the selection of air monitoring sites for pump placement.

The rating team consisted of two "core" raters who visited every study region, and two "local" raters in each study region. The local raters were regional EPA, GSA, or local city government staff.

A professional, two-day training course was held for the raters 1½ weeks before field work began. This produced a group of individuals with experience and training typical of those likely to be assessing ACM in real-world applications. Study Region 5 local raters did not attend the training course because the decision to include this city was made after the training course had taken place.

The rating team assessed approximately four predetermined sites in each of between 9 and 15 buildings in each of the study regions. The sites were selected to represent a variety of conditions, locations, and types of ACM. Table 5-1



CHAIN OF CUSTODY RECORD

Sample Site ____________________

Date Sampled ____________________

Shipped By ____________________

Date Shipped ____________________

Carrier ____________________

ID Number ____________ Test Number ____________

Invoice Number ____________________

Date Received ____________________

Received By ____________________

Condition ____________________

SAMPLE NUMBER	SAMPLE DESCRIPTION	SHIPPING CONDITION	RECEIVING CONDITION

Signature of Sender ____________________ Date ____________

Signature of Receiver ____________________ Date ____________

Figure 5-4. Chain-of-custody form for this study.

Table 5-1. List of Study Regions, Week of Rating, and Number of Buildings and Sites Within Buildings Rated in Each Study Region

Study region	Week of rating	Number of buildings	Number of sites[a]
1	March 23	15	64
2	April 6	9	37
3	April 20	11	47
4	May 4	11	52
5	May 18	14	57

[a] Rated by two or more raters.

---

lists the study regions, week of rating, and the number of buildings and sites. The study regions are numbered in the order in which they were sampled. This numbering scheme is not related to the regional classification used by either GSA or EPA. Each rater completed the form shown in Figure 5-5 in order to obtain the necessary assessment factors described in USEPA (1986a). This form contains the key factors discussed in USEPA (1986a) for assessing ACM (i.e., overall condition, potential for disturbance, and air flow) as well as other information. The exact definitions of these factors can be found in the Glossary (Appendix H). The rating team did not discuss the sites before or during rating in order to ensure that the ratings were accomplished independently.

After all predetermined sites in a building were rated by the team, additional information was collected in order to verify the building category and to collect information to select air monitoring sites. The location of the area thought to be the most damaged ACM in the building, based on GSA building records or information collected by the building inspector, was contained in a sealed envelope and opened by the rating team at the conclusion of the rating process. (Note that "most damaged" could mean good condition if there were no moderately or significantly damaged areas in the building.) The rating team was instructed to bulk sample this area to verify the presence of asbestos and any areas which they had visited and found to be in

Assessment Form

Building ID ______________________

Area ID __________________________

Type of ACM

Surfacing_____ Thermal System Insulation_____ Other______

Description ____
____
____

Condition

Percent Damage ____ %
Distribution of Damage: Localized _______ Even ______

Type of Damage:
Deterioration_____ Physical Damage_____ Water Damage _____

Description ____
____

Overall condition: Sig Damage____ Mod Damage____ Good____

Potential for Disturbance

Accessibility: High_____ Low _____
Description ____

Vibration: High____ Low____ None______
Source ____

Air Erosion: High_____ Low_____ None______
Source ____

Overall Potential for Disturbance:
High_____ Moderate_____ Low_____

Air Flow
In Air Flow? Yes_____ No_____
Type of Flow ____

Comments ____
____
____
____

Signed ________________________ Date __________

Figure 5-5. Assessment form for recording information about the ACM in a given area.

worse condition. Occasionally, the building escort suggested additional areas that were also bulk sampled.

Bulk sampling was performed following the random sampling procedures in USEPA (1985a), although convenience samples were collected in the following circumstances:

- Pipe wrap in fan/boiler room;
- Limited access to sprayed-on material due to piping, ductwork, etc.; and
- Specific requests by the building escort or management not to collect more than one sample per site.

Undamaged TSI, except for exposed material, was not sampled because that would violate GSA's asbestos management program guidelines. Only friable surfacing materials and TSI were sampled (e.g., ceiling and floor tiles were not sampled). The rating team kept detailed notes of the areas sampled and also sketched the location of the material. The bulk samples were carried back to the laboratory for analysis at the end of the rating period in each study region.

The purpose of bulk sampling the areas described above was to confirm the initial classification of buildings based on GSA records as Category 2 or Category 3. Depending on whether the areas rated contained asbestos or not, the buildings were reclassified as necessary prior to air sampling. These results are discussed in Section 7.

6.0 RESULTS OF THE FIELD TEST OF THE ASSESSMENT METHOD

6.1 DATA ANALYSIS

ACM condition for a specific area within a building can take one of three possible values: good, moderate damage, or significant damage. These values are coded as 1, 2, and 3, respectively. Likewise, potential for disturbance is rated as low, moderate, or high. These are coded as 1, 2, and 3, respectively. For the remainder of this report, potential for disturbance will be referred to as "disturbance." Air flow takes the values yes or no, coded as 1 and 0, respectively.

The data listing in Appendix A shows the responses of the individual core and local raters for each of the three assessment factors at each site. Table A-1 gives the condition of the sites, Table A-2 gives the disturbance rating of the sites, and Table A-3 shows the air flow of the site. The frequency of occurrence of each score is given in Appendix B.

Consistency of ratings may be measured in a variety of ways. One simple measure is the percentage of sites where perfect agreement occurs (i.e., all raters give the same rating). Another measure is the percentage of sites where minimum agreement occurs (i.e., at least one rater assigns the maximum rating and at least one rater assigns the minimum rating). While both measures have been calculated and summarized, neither distinguishes between situations where just one rater disagrees with the remaining raters from situations where there is little agreement among any of the raters. An "agreement" index, A, was developed to measure the overall degree of consistency among raters taking into account both the number and magnitude of disagreements. A is defined as 1 minus the sum of the differences between the raters' scores, normalized so it takes values between 0 and 1. It is calculated as:

$$A = 1 - \frac{\sum_{i<j}^{n} |X_i - X_j|}{\max}$$

where n = number of raters which rated the site;

X_i = response of the i^{th} rater; and

max = the theoretical maximum that the numerator can take for n raters.

When there is perfect agreement between raters at a site, A=1. A=0 indicates minimum agreement. A similar measurement of rater agreement was used in a previous EPA study (USEPA 1981). In that case the measure was divided by the number of comparisons rather than normalized to range from 0 to 1. Although the two measures are not quantitatively identical, the qualitative results of the two studies can be compared.

A-values were calculated for each site and averaged within study regions to provide a summary of rater consistency for each of the three assessment factors.

A statistical test was developed to determine whether the assessment factors generate more agreement than would be expected if the raters were assigning ratings at random. The probability distribution of A was calculated under the null hypothesis of random assessment. From this, the probability distribution of A averaged over sites was generated by computer simulation for each combination of number of ratings, number of raters, and number of sites. If the observed average is found in the upper tail of the distribution, it is unlikely that the ratings are being assigned at random. An observed average equal to the $(1-\alpha)$th percentile, i.e., a p-value of α, would be called statistically significant with a significance level equal to α.

6.2 ASSESSMENT RESULTS

Table 6-1 shows the percentages of sites with total agreement among raters and the percentages of sites having minimum agreement. Minimum agreement occurs at a site if at least one rater scores the lowest value of a factor and at least one rater scores the highest value of the factor. Note that all the percentages are sensitive to the number of raters present. Total agreement is more likely with fewer raters, while minimum agreement is more likely when there are more raters.

Overall, there is greater total agreement and less minimum agreement for condition than for disturbance, although the relationship varies slightly from study region to study region. The highest frequency of minimum agreement occurs in Study Region 5. High total agreement and minimum agreement for air flow are not surprising since there are only two ratings (0 and 1), and the 2 percentages must sum to 100.

In Figure 6-1, average A-values for condition, disturbance, and air flow are plotted by study region with study region numbered in chronological order. The A-value for a given site is based on the ratings of between two and four raters depending on how many raters were actually present at the site and whether all of the raters completed all the assessment factors at a site (there were occasional missing entries). Each average measure of consistency shown in Figure 6-1 has a significance level less than 0.05 when tested against random ratings. The study, therefore, indicates a tendency for consistency among raters.

Table 6-1. Percentages of Sites Which Showed Total Agreement Among Raters and the Percentages of Sites with Minimum Agreement Among Raters

Study region	Assessment factor	% Total agreement	% Minimum agreement
1	Condition	31.3	0
	Disturbance	35.9	4.7
	Air flow	55.6	44.4
2	Condition	48.6	0
	Disturbance	13.5	8.1
	Air flow	29.7	70.3
3	Condition	29.8	6.4
	Disturbance	25.5	4.3
	Air flow	72.3	27.7
4	Condition	38.5	1.9
	Disturbance	15.4	7.7
	Air flow	75.0	25.0
5	Condition	22.8	19.3
	Disturbance	17.5	19.3
	Air flow	66.7	33.3
All	Condition	33.1	5.8
	Disturbance	22.6	8.9
	Air flow	61.3	38.7

Note: Minimum agreement occurs at a site if at least one rater scores the lowest value of a factor and at least one rater scores the highest value of a factor.

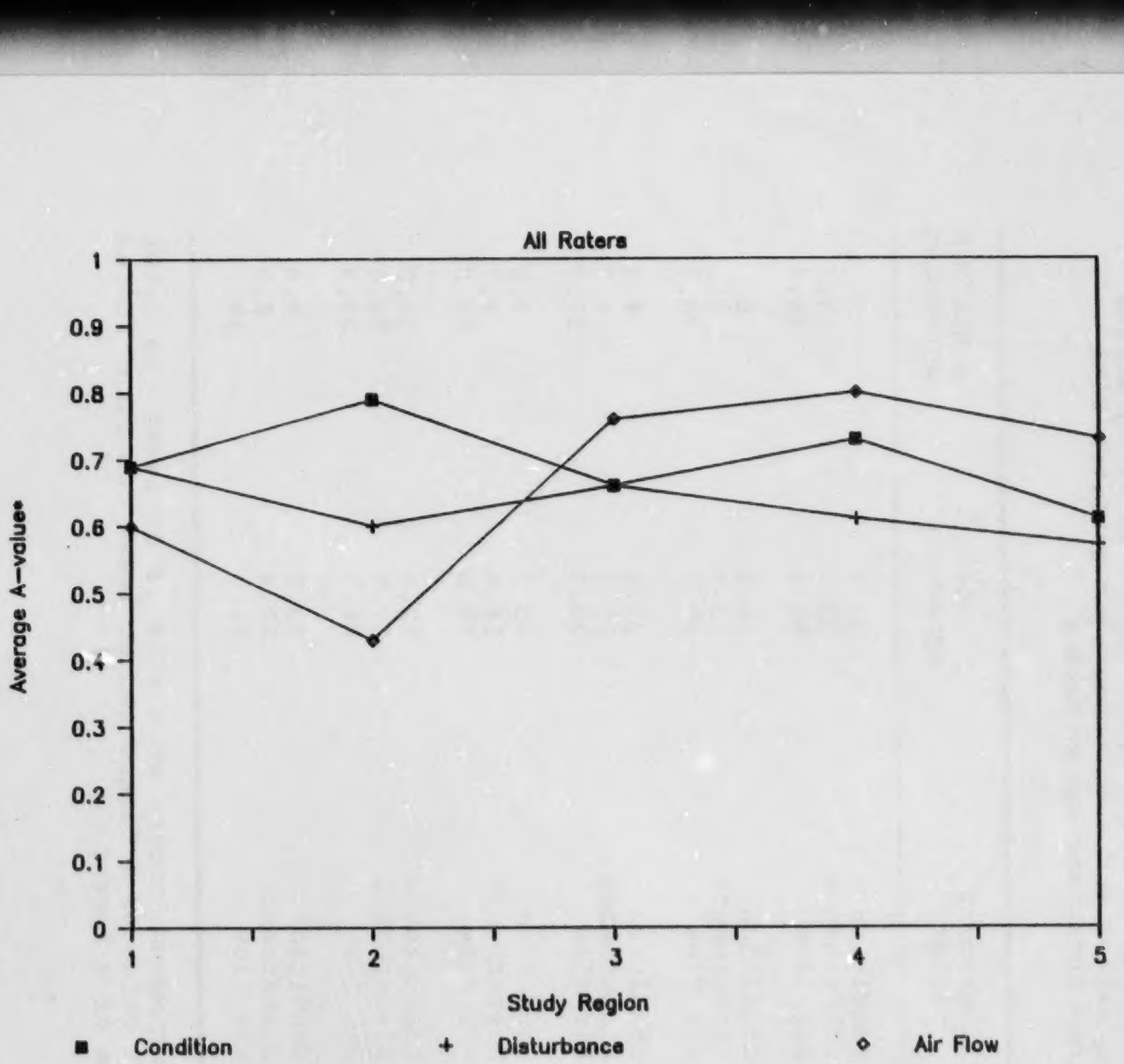


Figure 6-1. The average agreement index, also called the average A-value, for condition, disturbance, and air flow in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement.

The average A-value for condition tends to be higher than the A-value for disturbance. This suggests that the definition of condition used in this study can be applied more consistently than the definition of potential for disturbance. The average A-value for air flow varies from study region to study region. In the first two study regions there is less agreement on air flow than on condition and disturbance. In the last three study regions the opposite is true.

A previous EPA study on assessing ACM also showed greater consistency when rating condition (USEPA 1981). The assessment method used in that study differs from the current one, but factors related to condition (water damage, physical damage) showed greater rating consistency than those related to disturbance (accessibility, activity). The 1981 study considered a factor "air-moving system" which was more narrowly defined than in the present study and showed high consistency among raters.

A-values were also calculated for core and local raters separately (Figures 6-2, 6-3 and 6-4). The core raters were the same two individuals across all study regions, while the local raters were represented by different individuals in each study region. For condition and disturbance (Figures 6-2 and 6-3, respectively), the amount of agreement between the core raters begins at between 0.8 and 0.9 and remains fairly constant across study regions (with some slight improvement over time). For the core raters, all average A-values for condition and disturbance have p-values less than 0.05. In Study Region 1, local raters have about the same amount of agreement as the core raters. Local raters' level of agreement tends to decrease for the remaining study regions. For condition, the test of consistency among local raters had a significance level less than 0.05 in all study regions except Study Region 5. Study Region 5 raters did not attend the training course. A-values for disturbance have significance levels less than 0.05 only in Study Regions 1 and 4. For air flow (Figure 6-4), the relationship between the core and local raters varied from study region to study region. In Study Regions 2 and 4, the core raters show less agreement than the local raters. In Study Regions 1, 3, and 5, the local raters show less agreement. All air flow A-values have significance levels less than 0.05 with the exception of Study Region 2 for core raters and Study Region 1 for local raters.

6.3 CONCLUSIONS OF TEST OF ASSESSMENT METHOD

Based on the criterion of rater consistency, the assessment factors, as defined in this study, show promise as assessment tools for use in the field. Lack of consistency can be attributed, in part, to imprecision in definitions and lack of training, both of which can be remedied. This conclusion is based on the following results:

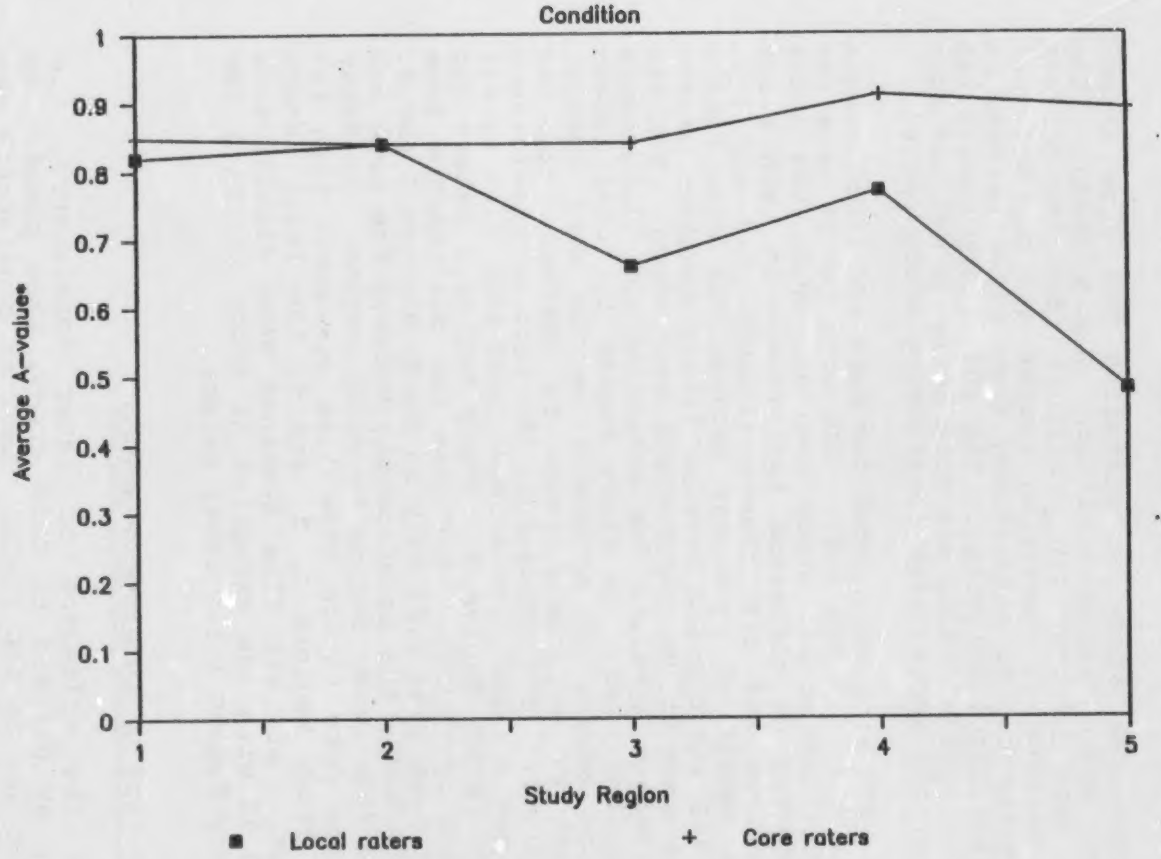


Figure 6-2. Average A-values for condition with core and local raters plotted separately in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement.

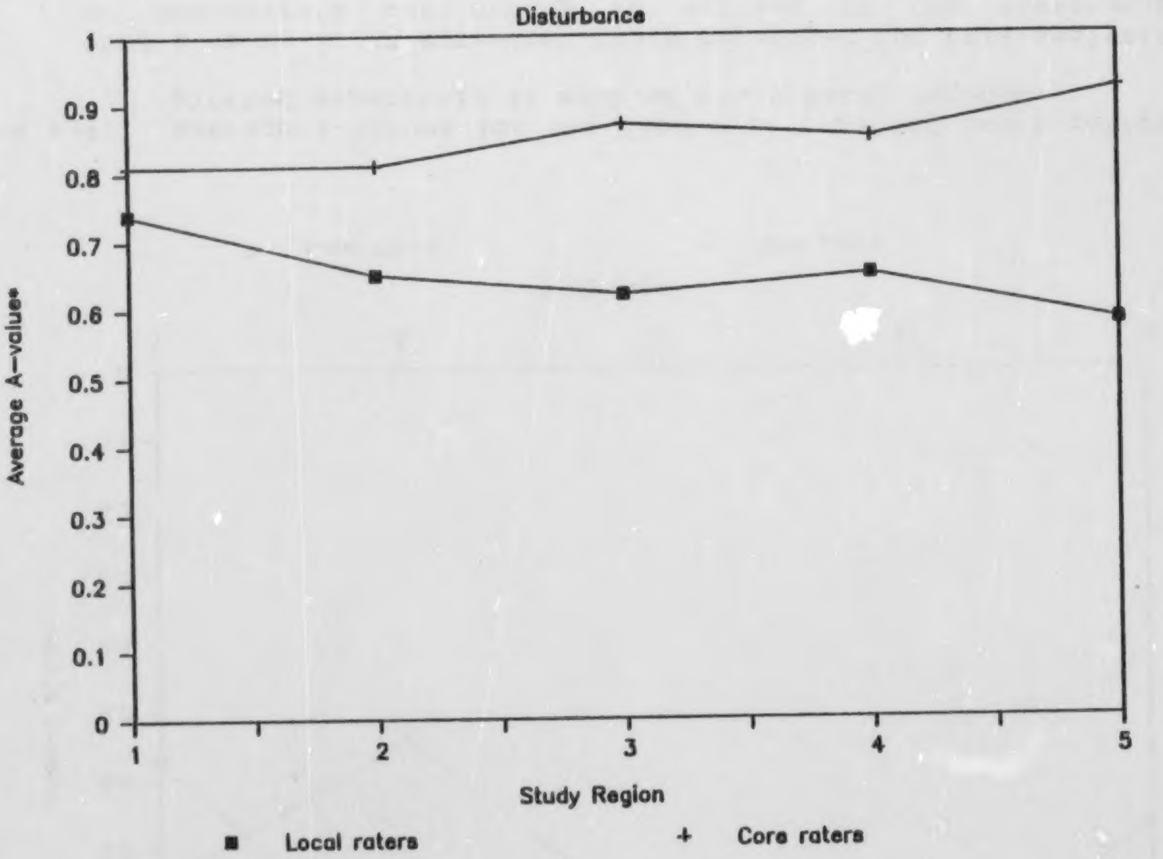


Figure 6-3. Average A-values for disturbance with core and local raters plotted separately in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement.

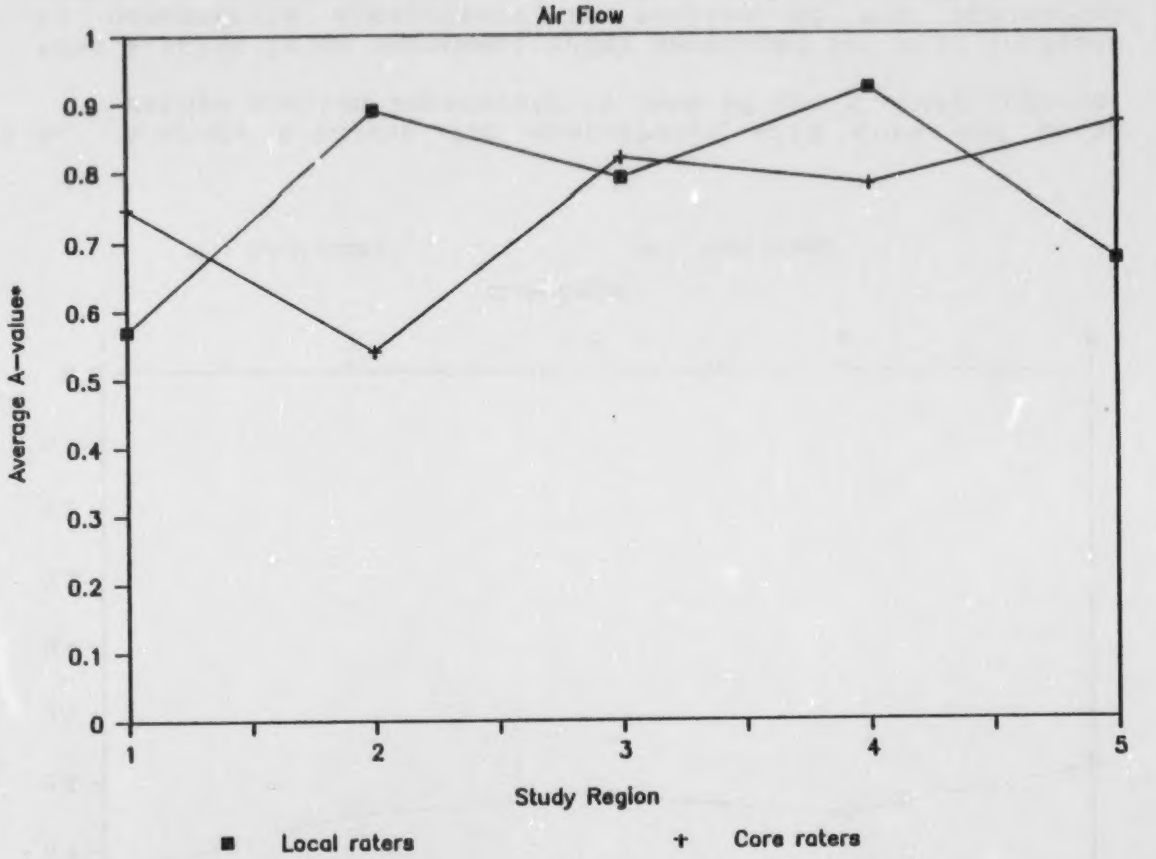


Figure 6-4. Average A-values for air flow with core and local raters plotted separately in each of the 5 study regions.

*The A-value is an agreement index developed for this analysis to demonstrate consistency in scoring of the assessment factors. A-values range from 1 for maximum agreement among raters to 0 for minimum agreement.

- Consistency between raters is significantly greater than would be predicted if assessment were at random.

- There is greater consistency among raters when assessing condition than when assessing potential for disturbance. In this study, condition was defined in quantitative terms (e.g., terms such as greater than 10% damage) whereas the definitions for disturbance were more qualitative. Consistency in air flow ratings varies from study region to study region, with low consistency in some study regions and high consistency in others. The present two-part scale does not distinguish significant air flow from very slight air flow. A three-part scale (high, moderate, and low/none) for air flow may increase consistency.

- Consistency between the core raters is greater than consistency between the local raters. The core raters had more experience in applying the assessment method.

- Region 5 local raters, who did not attend the training, showed the least consistency in assessing condition and potential for disturbance.

7.0 BULK SAMPLE ANALYSIS AND POLARIZED LIGHT MICROSCOPY QUALITY ASSURANCE

7.1 BULK SAMPLE ANALYSIS

All bulk samples collected by the building inspector and rating team were analyzed with polarized light microscopy (PLM), as per Appendix A of USEPA (1982). For the purposes of this study, however, only the information about presence (">1%") or absence ("none detected" or "trace") of asbestos was used.

The method described in USEPA (1982) is most commonly used to identify and quantify asbestos fibers in bulk samples. It can distinguish fibers of the serpentine group (chrysotile) from those of the amphibole group (amosite, crocidolite, anthophyllite, tremolite-actinolite), and is sensitive to asbestos content as low as 1%. Asbestos fibers are reported as area percentages of the total sample. This method is limited to fiber sizes greater than 1 μm in length.

Sample preparation involved gross examination to characterize the sample and to determine homogeneity. If the sample was not homogeneous, each phase was separated for individual identification. At least one microscope slide was prepared for each phase by teasing a small piece of sample from the bulk and mounting it on the slide with a refractive index oil ($n = 1.54$) and coverslip. All gross examinations and slide preparations were performed in the glovebox to protect the analyst.

Sample examination involved analysts trained in classical crystallography techniques. The specific techniques used depended upon the nature of the sample, but in general, the examination utilized magnifications of 20X to 400X, and at least four fields were counted.

The analytical laboratory used standard asbestos data forms (Figure 7-1), bound in a notebook format for recording all analytical data. Data were recorded in duplicate, with one copy remaining in the analyst's notebook, and the other being submitted to the data entry technician.

7.2 BULK SAMPLE AND POLARIZED LIGHT MICROSCOPY QUALITY ASSURANCE

The collection of bulk samples by the building inspector and rating team was a QA activity because this information was used to verify the classification of the building categories. The final classification of these buildings is discussed in Section 7.3. In addition, specific QA procedures

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ASBESTOS ANALYSIS WORKSHEET
ASBESTOS ANALYSIS GROUP

PROJECT: CONTRACT #

FIELD ID # ID # Facility ID #

SAMPLE LOCATION:

SAMPLE DESCRIPTION/CONDITION:

ASBESTOS FOUND: ____NONE DETECTED ____TRACE ____>1%

PLEASE COMPLETE FOR ALL ITEMS. ENTER "NONE DETECTED" IF NONE FOUND.

MATERIAL	PERCENT	IF A RANGE, SPECIFY HERE.
ASBESTOS:		
CHRYSOTILE	____	____ - ____
AMOSITE	____	____ - ____
OTHER ASBESTOS	____	____ - ____

SPECIFY OTHER TYPE(S) OF ASBESTOS: ____

FIBROUS NON-ASBESTOS:		
GLASS WOOL OR MINERAL WOOL	____	____ - ____
FIBERGLASS	____	____ - ____
CELLULOSE	____	____ - ____
OTHER FIBROUS NON-ASBESTOS MATERIALS	____	____ - ____

SPECIFY OTHER TYPE(S) OF FIBROUS NON-ASBESTOS: ____

NON-FIBROUS:		
PERLITE	____	____ - ____
VERMICULITE	____	____ - ____
OTHER NON-FIBROUS MATERIALS	____	____ - ____

SPECIFY OTHER TYPE(S) OF NON-FIBROUS: ____

DATE OF ANALYSIS: ANALYST:

Figure 7-1. Analytical data form for reporting bulk sample analysis.

were used for the bulk sample collection and analyses to ensure their precision and accuracy.

Chain-of-custody procedures were implemented for all samples collected during the project. Field custody procedures were used to document the location of a sample from the time of collection until its receipt by the analytical laboratory. At this point, internal laboratory records were used to document the handling of the sample through its final disposition.

Standard sample custody (traceability) procedures were used during this project. Each sample was labeled with a unique random identification number immediately after collection. This number was recorded in the field logbook along with the following information:

- Name(s) of the sampler;
- Date of collection;
- Sample location;
- Sketch of location (rating team only); and
- Comments.

A chain-of-custody form was filled out in the field for all samples. A copy of the form was included with each shipment of samples to the analytical laboratory. Figure 5-4 is a representative copy of the chain-of-custody form used during the project.

Upon receipt of the samples at the analytical laboratory, the following steps were taken:

- Sample labels were cross-checked with the accompanying custody form.
- Samples were logged in a master sample logbook.
- Prior to and after analysis, samples were stored in a controlled area.
- Samples handled by laboratory personnel were traced by proper log-in/log-out procedures.

Specific QA procedures were performed to estimate the precision and accuracy of the bulk sample collection and analyses: side-by-side duplicates, and external and replicate analyses. A side-by-side duplicate is a sample collected in the immediate area of the original sample but handled separately. The degree of agreement of the analyses of the original sample with its duplicate indicates the level of precision in the sample collection and field handling procedures. An external analysis is one in which the sample is analyzed a second time by another analytical laboratory. This type of analysis is performed as a quality control (QC) check on the performance of the method by the primary laboratory. The degree of agreement of the original analysis with the external analysis indicates the consistency of the method performance. A replicate analysis is one in which the same sample is analyzed twice by the analytical laboratory. The degree of agreement of the two analyses indicates the level of precision in the laboratory analysis procedures.

All three of the QA procedures described above were used for the analyses of the bulk samples in this study. The results of these QA samples indicated a very high level of precision and accuracy in the bulk sample collection and PLM analyses.

7.2.1 Side-by-Side Duplicates

A total of 279 bulk samples were collected by the building inspector and rating team in the field and analyzed for asbestos content. Of these 279 samples, 20 were collected in the field as side-by-side duplicates (20/259 = 8%). With respect to presence or absence of asbestos, all 20 of the side-by-side duplicates agreed with their original samples (100% agreement).

7.2.2 External Analyses

From the 279 bulk samples, 31 were randomly chosen for external analysis by a second laboratory (31/279 = 11%). With respect to the presence or absence of asbestos, 30 of the 31 externals agreed with their original samples (30/31 = 97% agreement). The one disagreement did not result in the misclassification of the building category as verified by additional bulk samples collected at that area by the rating team.

The primary analytical laboratory also performed its own QC checks. The laboratory participated in the EPA Asbestos Bulk Sample Analysis Quality Assurance Program. Sixteen of the EPA bulk QA samples (for which the "true" percentage of asbestos is known) were submitted as blind QC samples along with the field samples. With respect to the presence or absence of asbestos, all 16 of these results agreed with the original EPA determination (100% agreement).

7.2.3 Replicate Analyses

The analytical laboratory randomly chose 33 of the 279 field-collected samples and resubmitted them for replicate bulk sample analysis (33/279 = 12%). With respect to the presence or absence of asbestos, 32 of the 33 replicates agreed with the original result (32/33 = 97% agreement). The one disagreement did not result in the misclassification of the building category because that building's classification was based on another area where several samples were used to verify the presence of asbestos.

7.3 Building Classification

The goal of the building inspector was to verify the classification of the Category 1 and Category 2 buildings. A building's final classification as Category 1 depended on GSA records and the bulk sampling results. A Category 1 building is defined as one in which no friable asbestos-containing surfacing materials or TSI were noted in the GSA records and none was found during the building inspection. Asbestos was defined to be present in a bulk sample if the PLM analysis found greater than 1% asbestos. Absence of asbestos was defined as a result of "none detected" or "trace". Using these definitions, 6 of the 7 potential Category 1 buildings remained in that category. Because of the presence of asbestos in the remaining building, it was not included in the study.

In Category 2 buildings, the building inspector searched for and bulk sampled any friable surfacing material and TSI that were indicated in the GSA building records to contain damaged ACM and any areas in worse condition. The damaged areas found in these buildings were subsequently visited by the rating team. The functions of the rating team, in addition to field testing the assessment method, were to help verify the classification of buildings in Category 2 and 3 before air sampling. Based on the assessments of the rating team and the bulk sample results, the final classification of Category 2 and 3 buildings was achieved.

To assess the condition of the ACM in a given area, the rating team used definitions from USEPA (1986a) for the various conditions: good condition, moderate damage, and significant damage. The definitions of these condition categories for a given area are found in Appendix C. Only the assessments of the rating team leader (Core Rater 1, the most experienced member of the team) were used for the classification of building category. A building was classified as Category 2 if all or most of the areas with friable asbestos-containing surfacing materials or TSI were in good condition with perhaps a few areas (less than four) of moderate damage. Recall that the rating team visited the areas that were thought to be the most damaged ("most damaged" can mean good condition if there are no moderately or significantly damaged ACM areas in the building), and they bulk sampled those areas as well as any areas in worse condition. If an area contained greater than 1% asbestos in the bulk sample results and the condition was rated as significantly damaged, then the building would be reclassified as Category 3. Similarly, a number of moderately damaged areas with positive bulk sample results in one of these buildings would exclude the building from Category 2.

The areas in the Category 3 buildings were chosen based on the GSA building records. Since the rating team assessed what was thought to be the most damaged ACM area in each building and bulk sampled those and any areas in worse condition, this information was used to verify the condition of Category 3 buildings for air sampling. A building's final classification was defined as Category 3 if there was at least one significantly damaged area of friable asbestos-containing surfacing material or TSI, or there were numerous moderately damaged areas. Thus, most buildings placed in Category 3 were found to have positive (>1%) bulk sample results in areas with damaged ACM in the building. However, in 4 buildings (1 in Study Region 2, 1 in Study Region 3, 2 in Study Region 4), positive confirmation of damaged ACM within the building was not obtained. These buildings were classified as Category 3 because GSA records indicated the presence of damaged ACM within the buildings.

Forty-nine of the initial 67 buildings were selected for air monitoring. Table 7-1 shows the final classification of the 49 buildings by region. One of the remaining 18 buildings was not used for air sampling because it was initially classified as Category 1, but was found to contain asbestos. The remaining 17 buildings were excluded from air sampling because of geographic location (related to sampling logistics), uncertainty about classification as a Category 2 or 3 building, or, in the case of one building, because the ACM had been removed since the GSA records had been reviewed.

Table 7-1. Final Classification of Buildings in Categories 1, 2, and 3 in Each Study Region

Study region	Number of Category 1 buildings	Number of Category 2 buildings	Number of Category 3 buildings
1	2	2	5
2	1	1	8
3	0	0	10
4	2	1	7
5	1	2	7
Total:	6	6	37

Note: Only the 49 buildings chosen for air sampling were classified.

8.0 AIR MONITORING

8.1 FIELD METHODS

Air samples were collected in 49 buildings (9 in Study Region 1, 10 in each of Study Regions 2 through 5). Seven areas were sampled inside each building and one area was sampled outside. (One building, Building 44, could not be sampled outside and one building, Building 18, could be sampled at only six indoor sites.) About half of the sampling pumps were located near the most damaged ACM in the building. "Most damaged" could mean ACM in good condition if there were no moderately or significantly damaged materials in the building. The rest were placed in public areas nearby. Table 8-1 shows the five Study Regions, period of air sampling, and the number of buildings and sites at each building. A more detailed description of the air sampling field methods appears in Appendix D.

The air samples were collected on cellulose ester (Millipore) filters. Two side-by-side samples were drawn at each site: one of 5,000 L and one of 2,500 L. If the high volume sample contained too much debris for analysis, then the low volume sample was available for analysis. Each pump ran for two periods of approximately eight hours during consecutive weekdays during normal building activity. The volume of air sampled was determined from the flow rate readings taken at the beginning, during, and at the end of the sampling period. One field blank filter was collected in each building to check for contamination from sources other than the sampled air.

An independent auditor accompanied the field crew to each study region to ensure that all procedures were followed. After sampling was completed in each region, the filters were hand carried to the laboratory and analyzed by transmission electron microscopy (TEM).

8.2 AIR SAMPLE ANALYSIS

The TEM protocol is given in the Quality Assurance Plan (Hatfield et al. 1987). A summary appears in Appendix E of this report. Sample preparation involved collapsing the filter, plasma etching, and directly coating the filter with a thin layer of carbon by evaporative deposition under vacuum. The samples were cleared with acetone, leaving the particles attached to the carbon film. The samples were analyzed at a magnification of 20,000X. A minimum of ten grid openings with a total area of 0.062 sq. mm were examined on each filter. The total structure count includes asbestos fibers (structures with essentially parallel sides and an aspect ratio of 3:1 or greater) and asbestos bundles, clusters, and matrices as defined in the TEM

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Table 8-1. Period of Air Sampling Within Each Study Region

Study region	Period of air sampling	Number of buildings (sites) Category 1	Category 2	Category 3
1	April 12-17	2(16)	2(16)	5(40)
2	May 6-12	1(8)	1(8)	8(63)
3	May 20-28	0	0	10(80)
4	June 10-16	2(16)	1(8)	7(56)
5	June 21-26	1(8)	2(16)	7(55)

Note: The number of sites within buildings, including outdoor sites, is given in parentheses.)

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protocol. Two samples from Building 43 were too heavily loaded to be analyzed with the direct TEM method.

8.3 AIR SAMPLE AND TRANSMISSION ELECTRON MICROSCOPY QUALITY ASSURANCE

Chain-of-custody procedures were implemented for all air samples collected during the project. Field custody procedures were used to document the existence of a sample from the time of collection until received by the analytical laboratory. At this point, internal laboratory records were used to document the custody of the sample through its final disposition.

Standard sample custody (traceability) procedures were used during this project. Each sample was labeled with a unique random identification number immediately after collection. This number was recorded on the field data form along with the following information:

- Name(s) of the sampler;
- Date of collection;
- Sample location;

- Sketch of location; and
- Comments.

A chain-of-custody form was filled out in the field for all air samples. A copy of the form was included with each shipment of samples to the analytical laboratory. Figure 5-4 is a representative copy of the chain-of-custody form used during the project.

Specific QA procedures used to ensure the accuracy and precision of the air sample collection and TEM analyses included the collection of production lot and field blanks, field audits, laboratory audits, replicate and external analyses, and a study to further evaluate the results obtained by the TEM method.

Production lot blanks are filters chosen prior to the start of field work. They are analyzed by the analytical laboratory to check for filter contamination. Field blanks are filters taken into the field and handled in the same manner as exposed air sample filters. Their purpose is to check for contamination which might occur in the field but not as a result of air sampling. Field audits determine whether the field team is following set procedures. Laboratory audits determine the same for the analytical laboratory personnel. Replicate and external analyses serve the same purpose as discussed in Section 7 for PLM analyses.

8.3.1 Production Lot Blanks

Blank filters from prescreened production lots were randomly selected three times during the project: at the beginning of field activities, in the middle, and near completion. Each time, two filter cassettes were randomly selected from a previously unopened box of 50 filters. A total of 26 production lot blanks were selected in this way for analysis. The analysis of the production lot blanks indicated that there was not a problem with background filter contamination.

8.3.2 Field Blanks

During the pump set-up, preloaded filter cassettes were selected as field blanks. These filters were labeled and handled in an identical manner as were the sample filters, except that they were not attached to the sampling pump. The filters were capped during active sampling periods and open faced during the non-run hours when the actual sample cassettes were also open faced. Field blanks were collected in 30 of the buildings sampled. The purpose of the field blanks was to measure contamination which might occur during periods when the pumps were not running.

Of the 30 field blanks collected, 19 were selected for analysis. If a high level of contamination was found from the analysis results of the 19 blanks, the remaining 11 blanks would have been analyzed. The 19 blanks that were analyzed were chosen at random from the 30 blanks collected. No structures were detected in 18 of the 19 field blanks that were analyzed. A single fiber was counted on the remaining blank. This level of blank contamination corresponds to an airborne asbestos structure concentration of 0.00015 s/cc when 5,000 L of air is collected, a very low level of contamination. Thus, it was not necessary to analyze the remaining blanks.

8.3.3 Flow Rate Calibration

All data collected in the field were transcribed from the field data sheets onto a computer disk. Flow readings were corrected to standard temperature and pressure (STP) via internal calculations built into the computer spreadsheet.

Since the flow rate was controlled by limiting orifices and no adjustment could have been made to the diaphragm vacuum pump, the equipment limited to calibration were the rotameters, barometric gauges, and thermometers. Two rotameters of differing capacity were used to measure the flow rate under field conditions. A 0 to 5 Lpm rotameter was used to monitor the 2.5 Lpm limiting orifice side, and a 0 to 20 Lpm rotameter was used on the 5 Lpm orifice side. The procedure to calibrate rotameters to STP used a bubble tube as a secondary standard. The procedure is described in USEPA (1977).

Using STP, a calibration curve was developed for each rotameter. Upon return from the field, the recordings made in the field were compared to the calibration curve, and a STP flow was achieved. The STP flow was then recalculated using the computer to finalize the flow-to-field operating conditions. A random set of final flow volumes was recalculated as a confirmation check. Final flows, their matching random I.D. numbers and locations were tabulated and matched by a computer with the TEM results from the electron microscopy laboratory.

8.3.4 Field Audits

Five field audits were conducted by an independent field auditor, one audit in each of the study regions. The field auditor accompanied the field crew during pump set-up in several buildings per study region. He checked to be sure that the field crew was following the guidelines set forth in the Quality

Assurance Plan (Hatfield et al. 1987), and documented any violations in procedures so they could be corrected. For example, an air hose on one pump was found to be punctured. This was noted and immediately corrected. The field auditor also measured 216 flow rates in pumps in these buildings. This was done in order to estimate the relative accuracy of the flow rates, defined as [(field value-audit value)/(audit value)] x 100. The percentage of flow rates within ± 20% relative accuracy was 99%.

8.3.5 Laboratory Audits

To ensure the accuracy of the air sample analyses using TEM, two laboratory audits were performed. An independent laboratory auditor visited the TEM analytical laboratory to verify that all procedures specified in the Quality Assurance Plan (Hatfield et al. 1987) were followed. Two audits were conducted, one at the beginning of the analyses and one at the end. The auditor concluded that:

- The sample identification was traceable from sample acceptance through preparation, analysis and reporting.
- The sample preparation was done according to protocol, with the exception of the use of scissors instead of a scalpel for the cutting of filters.
- The TEM analysis was done according to protocol.
- The reporting procedure was implemented properly and was accurate.

8.3.6 Replicate and External Analyses

Twenty air samples, four from each study region, were selected at random to investigate within and between laboratory performance. The samples were reanalyzed by the original laboratory (replicate analysis) and by a second laboratory (external analysis). These 40 QC analyses increase the total number of analyses by just over 10%. Within each study region, three samples were selected at random from sites within Category 2 and 3 buildings. The fourth sample was selected from the outdoor and Category 1 sites. The samples were recoded to avoid analyst bias in the replicate analysis.

Table 8-2 presents the results of the original, replicate, and external analyses. No asbestos structures were

Table 8-2. Comparison of Airborne Asbestos Concentrations Estimated by the Original, Replicate (Same Laboratory), and External (Different Laboratory) TEM Analysis

Original		Replicate		External	
Number of structures	s/cc	Number of structures	s/cc	Number of structures	s/cc
0	0.000	0	0.000	0	0.000
1	0.001	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
1	0.003	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
1	0.003	1	0.003	0	0.000
0	0.000	1	0.003	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000
0	0.000	1	0.002	0	0.000
0	0.000	1	0.003	0	0.000
0	0.000	0	0.000	1	0.002
0	0.000	0	0.000	0	0.000
0	0.000	0	0.000	0	0.000

detected on 13 of the 20 filters. One or more of the three analyses detected a single structure on the remaining seven filters.

There is no evidence of inconsistency among the three sets of analyses. A Wilcoxon signed-rank test (Sokal and Rohlf 1969) did not detect any significant tendency for any one analysis (original, replicate, or external) to give higher or lower structure counts than any other.

A confidence interval for the mean structure count can be constructed by assuming a statistical distribution for the counts. A Poisson distribution gives a 95% confidence interval of (0, 3.0) when zero structures are counted. Therefore, an observation of zero structures is not inconsistent with a mean of 3 structures, indicating that the differences of a single structure between analyses are not significant. This conclusion is even stronger if structure counts follow a negative binomial distribution. The confidence interval for a negative binomial is wider than the corresponding interval for a Poisson distribution.

8.3.7 Examination of Additional Grid Openings

Sixteen air samples were selected for additional analysis to determine if the 10 grid openings specified by the TEM protocol provide estimates of sufficient precision for the purposes of the study. The 16 samples were selected as follows to provide a range of structure counts:

- 4 "indoor" samples which had structure counts of 3 or more in the first 10 grid openings counted;
- 8 "indoor" samples which had structure counts of 0 in the first 10 grid openings;
- 2 "outdoor" samples; and
- 2 field blanks.

An additional 40 grid openings, giving a total of 50, were examined on each sample and the number of structures in each opening recorded.

The precision of the TEM analysis was investigated by fitting a negative binomial distribution to the number of asbestos structures per grid opening. The negative binomial is a discrete distribution which is often used to describe clumped or aggregated populations. Javitz and Fowler (1981) found that the negative binomial was superior to the Poisson for describing asbestos structure counts obtained by electron microscopy. The variance of the negative binomial is $m(m + k)/k$ where m is the mean and k is a measure of aggregation. As k increases, the variance decreases and, consequently, the precision of estimated airborne asbestos concentrations increases. The Poisson distribution is a limiting case of the negative binomial as k becomes very large.

The parameter k was estimated for each filter with a non-zero structure count. Given k, the precision of the structure count can be determined as a function of the number of grid openings counted. (Details are given in Appendix F.)

Estimates of the mean number of structures per grid opening (m), the variance, and k for each filter are given in Table 8-3. Estimates of k equal to infinity indicate that the variance does not exceed the mean and that a Poisson or more uniform distribution is more appropriate than the negative binomial. This implies a small variance and hence increased precision.

No asbestos structures were counted on eight of the 16 filters. The eight include the two field blanks and the two outdoor samples. Of the eight filters with non-zero counts, five have estimates of k equal to infinity. The remaining three estimates of k are 0.6, 0.4, and 0.07.

For k equal to infinity, i.e., a Poisson distribution, a 95% confidence interval for the true structure count when no structures are counted in 10 grid openings is (0, 3.0). The size of the confidence interval increases slightly to (0, 3.1) as k decreases to 0.4. Thus, for values of k greater than or equal to 0.4 the examination of 10 grid openings in this study yields an airborne asbestos concentration that is sufficiently precise to distinguish 0 s/cc from 0.009 s/cc with high probability. (In this study one structure corresponds to approximately 0.003 s/cc.)

The data in Table 8-3 indicate that k is usually greater than 0.4, but that smaller values, such as k = 0.07 are possible. The standard deviation of this estimate of k is 0.9. For k = 0.07, a 95% confidence interval for the true structure count when no structures are counted in 10 grid openings is (0, 50). If the number of grid openings counted is increased to 50, the confidence interval shrinks to (0, 4.7).

Of the 16 filters examined, all but one indicate that examination of 10 grid openings is sufficient to distinguish 0 s/cc from 0.009 s/cc with high probability. Although, without additional data, it is difficult to predict how frequently exceptions will occur, the results suggest that examination of additional grid openings is generally unnecessary unless higher precision is required.

Table 8-3. Estimated Mean, Variance, and Value of k for the Number of Structures Counted Per Grid Opening Based on Examination of 50 Openings

	Openings 1-10	Openings 1-50		
Type of filter	Mean	Mean	Var	k
Indoor with 3 or more structures in openings 1-10	1.1	0.36	0.52	0.60
	0.3	0.18	0.27	0.41
	0.4	0.12	0.11	∞
	0.3	0.1	0.21	0.07
Indoor with 0 structures in openings 1-10	0	0.02	0.02	∞
	0	0.02	0.02	∞
	0	0	0	-
	0	0	0	-
	0	0	0	-
	0	0	0	-
	0	0.02	0.02	∞
	0	0.04	0.04	∞
Outdoor	0	0	0	-
	0	0	0	-
Field blank	0	0	0	-
	0	0	0	-

8.4 ANALYSIS OF AIR MONITORING DATA

8.4.1 Methods

For each of the 387 air samples collected and analyzed, an estimate of airborne asbestos concentration, c, in structures per cubic centimeter (s/cc) is given by:

$$c = (ns * A/a)/V$$

where

ns = the number of structures counted in the microscope;

A = the effective area of the filter;

a = the area of filter examined; and

V = the volume of air collected (in cubic centimeters).

The area of filter examined is calculated by multiplying the number of grid openings by the area of one grid opening. The analytical sensitivity is the smallest value, other than zero, that c can take. It corresponds to the observation of a single structure and depends on the values of A, a and V. In this study, the analytical sensitivity for most samples is approximately 0.003 s/cc.

Individual buildings are the basic statistical units for comparisons between different building categories and between indoor and outdoor levels. The airborne asbestos level in each building was estimated by the arithmetic mean of the samples. The distribution of these building averages was plotted and summary statistics (percentiles, mean, standard deviation) calculated for each building category and for the outdoor measurements.

Differences of distributions of airborne asbestos levels between building categories are indicated by the plots and tables of summary statistics. A statistical test was applied to provide a quantitative measure of the strength of evidence associated with observed differences (i.e., probabilities that the observed differences may have occurred only by chance were estimated). A "p-value," the level of significance, is reported for each comparison. The p-value is the probability of obtaining a difference as great or greater than the difference observed under the hypothesis that no true difference exists between the categories being compared. A small p-value indicates that the magnitude of the observed difference is unlikely under the hypothesis of no true difference, and therefore lends support to the alternative hypothesis, namely that the difference is real.

A permutation (also referred to as randomization) test (Cox and Hinckley 1974, Section 6.2) was used to test for differences between building categories and outdoors. (See also Edgington 1987 for a discussion of randomization tests.) Medians were chosen to represent the distributions of airborne asbestos levels. The median is appropriate for summarizing the location of this type of data because it gives equal weight to large and small data values and is not unduly influenced by a small number of extreme values. The permutation approach, rather than analysis of variance or Student's t-test, was used because the data contained a large number of zero observations. In previous air monitoring studies, where the majority of measured airborne asbestos concentrations were greater than zero, a log transformation was used to equalize variances prior to analysis by standard analysis of variance techniques (USEPA 1985b, 1986b; Tuckfield et al. 1987).

Under the null hypothesis of the permutation test, each of the 387 airborne asbestos measurements is an independent observation from the same probability distribution. Therefore, every possible permutation of the 387 values is equally likely. The distribution of any given statistic (e.g., the difference between two building category medians) under the null hypothesis can be determined by calculating the value of the statistic for each possible permutation and tabulating the frequency of occurrence of each value. The enumeration of every possible permutation is impractical for large data sets. Instead, the distribution of the statistic is based on a random sample of all possible permutations. The precision of any estimated percentile is determined by the size of the random sample.

A random sample of 1,000 permutations of the 387 airborne asbestos measurements was used to estimate the distribution of the differences between building category and outdoor medians under the null hypothesis that all airborne asbestos measurements are independent observations from the same probability distribution. For each permutation, the difference between medians was calculated in the same way as for the original data, i.e., measurements were averaged within a building, the median of each building category and outdoors was determined, and the difference between medians calculated. With 1,000 replications, the width of an approximate confidence interval for the 95th percentile is 0.02. The p-value for each observed difference is read directly from the estimated distribution. For example, if an observed difference corresponded to the 97th percentile of the distribution estimated under the null hypothesis, the p-value would be 0.03.

The p-values obtained in this way do not take into account the fact that several comparisons are being made simultaneously. Although the reported p-values may be smaller than a p-value obtained from the joint probability distribution governing all comparisons simultaneously, the reported values indicate which observed differences are most consistent with the null hypothesis of no true difference, and which provide support for the alternative hypothesis that a true difference exists.

The permutation method can also be used to compare different building categories using indoor-outdoor differences. This can be thought of as adjusting each indoor measurement for outdoor levels by subtracting the outdoor measurement. A test using adjusted data will be more powerful if the adjustment reduces the variance of the data. As will be seen below with this particular data set, all but 7 of the outdoor values were zero. For most of the data points, adjusting for outdoor levels has no effect. For the 7 buildings with non-zero outdoor levels (one structure observed), the adjustment results in a negative building mean because none of these buildings has an average indoor level as high as one structure per sample. The adjusted data have a higher variance than the unadjusted data. For this data set, adjusting for outdoor levels conveys no advantage and results in a less powerful statistical test. Therefore, this approach was not used.

8.4.2 Results

The estimated airborne asbestos concentration for each sample is given in Appendix G. No asbestos structures were detected in 83% of the 387 samples. For one sample from Building 23, the TEM result, a zero structure count, was reported after the statistical analysis was completed. This 388th sample is not included in any of the following tables or analyses. The maximum number of structures counted on a single sample was 11, corresponding to an airborne asbestos concentration at that site of 0.033 s/cc. This sample was collected in Building 2, which was categorized as containing no ACM (Category 1). No asbestos structures were observed on five of the remaining six filters collected in the building; the remaining filter had one structure. Neither GSA, nor the building inspector for this study, identified ACM despite thorough inspections of the building and analyses of bulk samples. The reason for this unusually high value is unknown. (The next highest airborne asbestos concentration at a single site is 0.013 s/cc.) The source of asbestos structures could not be found.

Figure 8-1 presents scatter plots of the average airborne asbestos concentration in each building, by building category, and for the 48 individual outdoor samples. The medians of each category are also shown. With the exception of the one Category 1 building, the highest average airborne asbestos concentrations occur in buildings from Category 3. However, in 27% of the buildings in Category 3, no asbestos structures were detected at the indoor sites. (No asbestos structures were detected in 16% of the Category 2 buildings, 50% of the Category 1 buildings, and 85% of the outdoor sites.)

The medians and arithmetic means of the average airborne asbestos concentrations for each building category and outdoor samples are reported in Table 8-4. Outdoor samples have the smallest median, followed by buildings from Category 1, buildings from Category 2, and finally, buildings from Category 3. The arithmetic mean of Category 1 is greatly influenced by the one unusually high value in that category, although the absolute magnitude of the mean is still very small. The other means follow the same trend as the medians. The outdoor means by building category, 0.00043, 0.00048, and 0.00036 s/cc for Categories 1, 2, and 3, respectively, do not show any apparent trend. Therefore, the trend in indoor means with

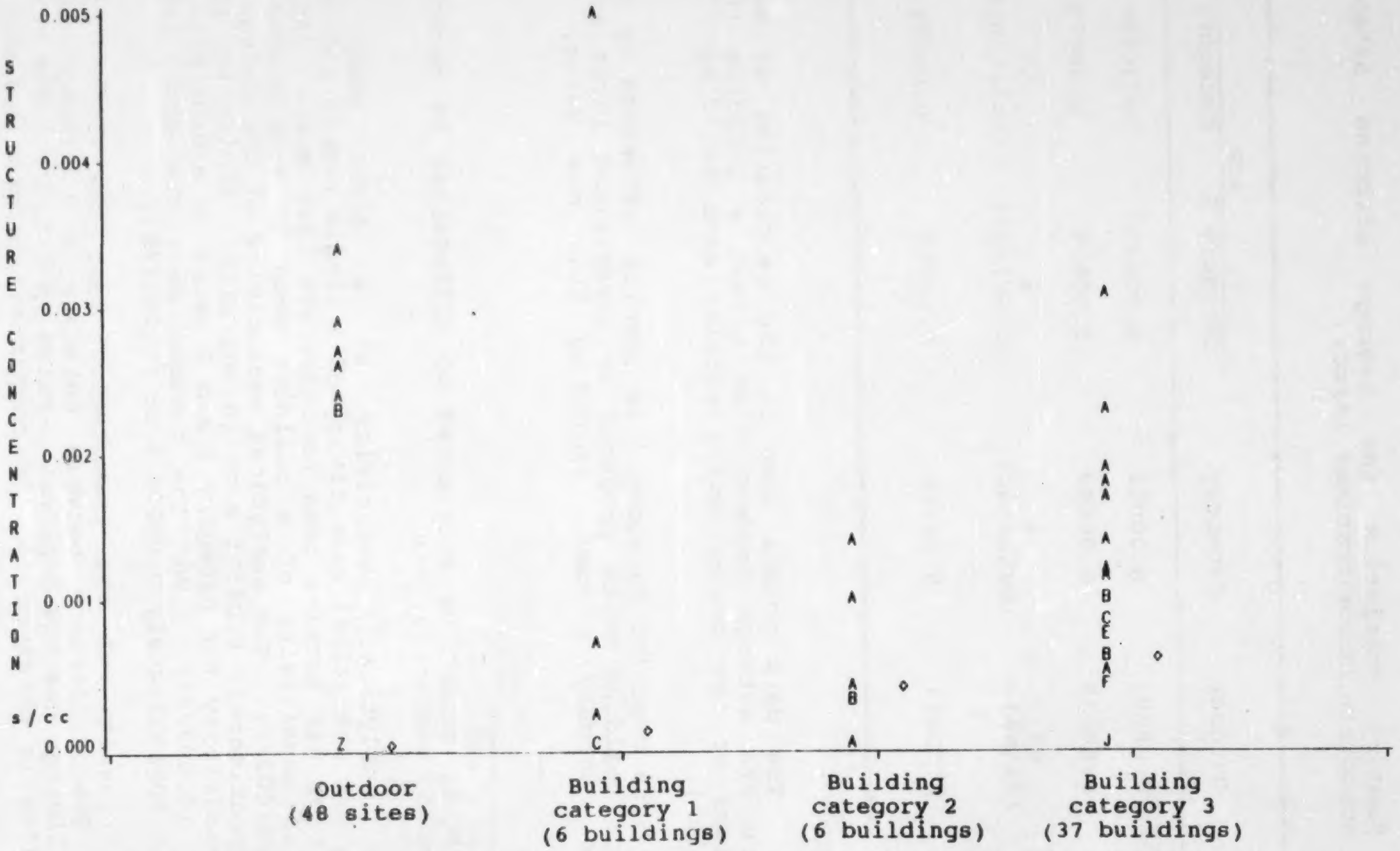

Figure 8-1. Scatter plots*and medians of the average airborne asbestos structure concentrations for each building category and outdoors.

*The data points for each scatter plot are the average concentration within a building (for indoor samples) or the concentration outside each building (for outdoor samples). A=1 data point, B=2 data points, ..., J=10 data points, and Z=41 data points. The diamond represents the median of the data points in each scatter plot.

Table 8-4. Summary Statistics for Average Airborne Asbestos Structure Concentrations (s/cc)

			ACM	
Statistic	Outdoor	Category 1	Category 2	Category 3
Median	<0.00001	0.00010	0.00040	0.00058
Mean	0.00039	0.00099	0.00059	0.00073
Sample size	48 (sites)	6 (buildings)	6 (buildings)	37 (buildings)
Standard deviation	0.00096	0.00198	0.00052	0.00072

Notes:

1. The data points used in the calculation of each statistic are the average concentration within a building (for indoor samples) or the concentration outside each building (for outdoor samples).

2. The mean for Category 1 is heavily influenced by one sample in one building which produced an unexplained large s/cc value. The Category 1 mean, excluding this one value, is 0.00020 s/cc.

building category cannot be attributed to differences in outdoor airborne asbestos concentrations.

The analytical sensitivity of a given mean is approximately the analytical sensitivity of a single sample divided by the number of air samples used to calculate that mean. Thus, the analytical sensitivity of a building mean is approximately 0.0004 s/cc (0.003/7). The analytical sensitivity of the Category 3 mean is approximately 0.00001 s/cc (0.003/255). Similarly, the analytical sensitivity for Category 1 and 2 means is approximately 0.00007 s/cc (0.003/42). For the outdoor mean the analytical sensitivity is approximately 0.00006 s/cc (0.003/48).

The results of the permutation test are listed in Table 8-5. The difference between Category 3 buildings and Category 1 buildings has the smallest p-value ($p < 0.02$). The next smallest p-value is obtained for the comparison between buildings

Table 8-5. Results of Randomization Test Indicating the Statistical P-Values for Differences between Median Airborne Asbestos Concentrations in Each of the Three Building Categories and Outdoor Concentrations

Comparison	Difference between medians (s/cc)	P-value[a]
Category 1 versus outdoor	0.00010	$p < 0.96$
Category 2 versus outdoor	0.00040	$p < 0.65$
Category 3 versus outdoor	0.00058	$p < 0.09$[b]
Category 2 versus Category 1	0.00030	$p < 0.21$
Category 3 versus Category 1	0.00048	$p < 0.02$[b]
Category 3 versus Category 2	0.00018	$p < 0.18$

[a] Probability of obtaining a difference as great or greater than the difference observed when there are no real differences among building categories or between a building category and the outdoor air.

[b] This p-value is based on 2,000 replications to provide additional precision.

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in Category 3 and outdoors ($p < 0.09$). The p-values for the remaining comparisons are 0.18 or greater. Estimates of indoor asbestos levels are more precise than estimates of outdoor levels because indoor levels are based on several samples per building. Thus, an observed difference between two building category medians corresponds to a smaller p-value than the same observed difference between a building category median and the outdoor median.

REFERENCES

Bishop, YMM, Fienberg SE, Holland PW. 1980. Discrete multivariate analysis: Theory and practice. Cambridge, MA: MIT Press.

Cox DR, Hinckley DV. 1974. Theoretical Statistics. London: Chapman and Hall.

Deming WE. 1950. Some Theory of Sampling. New York: John Wiley and Sons.

Edgington, ES. 1987. Randomization Tests (2nd edition). New York: Marcel Dekker, Inc.

Javitz HS, Fowler DP. 1981. Statistical analysis of microscopic counting data, in "Electron Microscopy and X-ray Applications," Russell PA (ed.), Ann Arbor Science.

Hatfield J, Leczynski B, Chesson J et al. 1987. Battelle Columbus Division. Public buildings study quality assurance plan. Final report. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-4243.

Miller, RG. 1981. Simultaneous statistical inference (2nd edition). New York: Springer-Verlag.

Rogers, J. 1987. Westat, Inc. Additional analysis of data collected in the asbestos in buildings survey. Draft final report. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-4243.

Sokal, RR, Rohlf, FJ. 1969. Biometry. San Francisco: W.H. Freeman.

Tuckfield RC, Chesson J, Tsay Y-L, et al. 1987. Battelle Columbus Division. Evaluation of asbestos abatement techniques phase III: removal. Draft final report. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-4243.

USEPA. 1977. U.S. Environmental Protection Agency. Quality assurance handbook for air pollution measurement systems, volume II - ambient air specific methods. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA 600/4-77-027a.

USEPA. 1981. U.S. Environmental Protection Agency. Asbestos in schools. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA 560/5-81-002.

USEPA. 1982. U.S. Environmental Protection Agency. Friable asbestos-containing materials in schools: identification and modifications. Washington, DC: Office of Toxic Substances, U.S. Enviornmental Protection Agency. 40 CFR Part 763.

USEPA. 1985a. U.S. Environmental Protection Agency. Asbestos in buildings: simplified sampling scheme for friable surfacing materials. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA 560/5-85-030a.

USEPA. 1985b. U.S. Environmental Protection Agency. Evaluation of asbestos abatement techniques phase I: removal. Washington, DC: Office of Toxic Substances, U.S. Enviornmental Protection Agency. EPA 560/5-85-019.

USEPA. 1986a. U.S. Environmental Protection Agency. Guidance for assessing and managing exposure to asbestos in buildings. Draft Report. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-4243.

USEPA. 1986b. U.S. Environmental Protection Agency. Evaluation of asbestos abatement techniques phase II: encapsulation with latex paint. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA 560/5-86-016.

Yamate G, Agarwal SC, Gibbons RD. 1984. Methodology for the measurement of airborne asbestos by electron microscopy. Draft report. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3266.

APPENDIX A

RESPONSES OF INDIVIDUAL RATERS IN EACH ASSESSED AREA WITHIN EACH REGION TO CONDITION, POTENTIAL FOR DISTURBANCE, AND AIR FLOW FACTORS

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TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
13	1	1	1	2	2
13	2	3	2	3	3
13	4	1	1	2	2
13	6	3	3	3	3
13	7	3	3	3	3
14	1	3	3	3	3
14	2	1	1	1	1
14	3	1	1	2	1
14	4	2	2	2	3
14	7	3	.	.	.
15	1	2	2	3	.
15	2	2	3	3	.
15	3	3	2	3	.
15	4	3	2	3	.
16	1	2	3	3	3
16	3	3	2	2	3
16	4	2	2	2	2
16	7	3	3	3	3
16	8	2	.	.	.
17	1	2	2	2	2
17	2	2	2	3	2
17	3	2	2	2	3
17	4	2	2	2	3
17	5	1	1	.	.
50	1	2	3	2	3
50	[illegible]	2	2	2	3
50	3	2	2	2	3
50	4	2	2	2	3
51	1	2	2	2	3
51	2	2	3	3	3
51	3	3	3	3	3
51	4	1	1	1	1
52	1	2	3	3	3
52	2	2	2	3	3
52	3	3	2	3	3
52	4	2	2	1	1
53	2	2	.	3	3
53	3	2	3	3	3
53	4	2	1	2	2
53	8	2	2	2	3
54	1	2	2	2	3
54	3	3	3	3	3
54	4	2	.	3	3
54	5	2	.	3	3
54	8	3	.	.	.
55	1	1	1	.	1
55	2	2	2	.	2
55	3	2	3	.	3
55	4	3	3	.	3
56	1	2	.	.	3
56	2	2	.	.	3

Preceding page blank

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
56	3	2	2	.	3
56	4	2	2	.	3
57	1	2	3	3	.
57	2	3	3	2	.
57	4	1	1	2	.
57	5	2	1	2	.
7	1	2	1	2	.
7	2	2	2	2	.
7	3	1	1	1	.
7	4	3	3	3	.
7	7	3	3	.	.
7	8	3	3	.	.
8	1	2	2	2	.
8	2	1	1	2	.
8	3	2	1	2	.
8	4	2	1	2	.

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          TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
                     SEPARATED BY REGION, BUILDING, AND AREA
                     1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

----------------------------------------------- REGION=2 -----------------------------------------------

          BUILDING          AREA      CORE RATER      CORE RATER      LOCAL RATER     LOCAL RATER
                                      ONE             TWO             ONE             TWO

          18                   1               1               1               .               1
          18                   2               2               3               3               2
          18                   3               2               2               2               2
          18                   4               1               1               2               1
          18                   8               2               3               3               2
          19                   1               1               2               1               2
          19                   2               3               3               3               3
          19                   3               3               3               3               2
          19                   4               2               2               2               2
          19                   7               .               .               .               .
          19                   8               .               .               .               .
          19                   9               .               .               .               .
          20                   1               2               3               3               3
          20                   2               2               3               3               3
          20                   3               1               2               1               1
          20                   4               2               3               2               2
          20                   5               .               .               .               .
          20                   8               .               .               .               .
          21                   1               2               .               2               1
          21                   2               3               3               3               3
          21                   3               2               2               3               2
          21                   4               2               2               2               2
          22                   1               2               2               3               2
          22                   2               3               3               3               3
          22                   3               1               1               1               1
          22                   4               2               2               2               2
          23                   1               1               1               1               1
          23                   2               2               2               3               2
          23                   3               2               2               2               2
          23                   4               3               3               3               3
          24                   1               2               3               3               3
          24                   2               2               .               3               3
          24                   4               3               3               3               3
          24                   5               2               2               2               2
          25                   1               1               1               1               1
          25                   2               2               .               2               2
          25                   3               1               2               1               1
          25                   4               2               3               3               2
          9                    1               2               2               2               1
          9                    2               1               1               1               1
          9                    3               2               2               .               2
          9                    4               2               3               3               3
```

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=3 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
26	1	3	2	2	.
26	2	2	2	2	.
26	3	2	2	2	.
26	4	2	2	1	.
27	1	3	3	2	3
27	2	2	1	3	1
27	3	2	2	2	2
27	4	3	3	3	3
27	8	2	3	2	2
28	1	2	2	1	3
28	2	2	2	1	3
28	3	1	2	1	2
28	4	1	2	1	1
28	5	.	.	.	.
28	6	.	.	.	.
29	1	2	2	3	3
29	2	2	2	2	3
29	3	2	2	2	3
29	4	2	1	2	2
30	1	2	3	2	3
30	3	3	3	.	.
30	4	2	2	2	2
30	6	2	2	3	3
30	8	2	3	2	3
31	1	3	3	2	3
31	2	2	2	2	3
31	3	2	3	2	3
31	4	2	3	3	3
32	1	3	3	3	.
32	2	2	1	2	.
32	4	2	2	2	.
32	6	2	2	1	.
32	9	3	3	2	.
33	1	3	3	2	.
33	4	2	2	2	.
33	5	3	3	2	.
33	9	2	2	2	.
34	1	3	3	2	.
34	2	2	1	1	.
34	3	2	2	3	.
34	4	2	2	2	.
35	1	2	1	1	2
35	2	1	1	1	1
35	3	2	2	2	.
35	4	2	3	2	3
58	1	2	2	2	3
58	2	2	3	3	3
58	3	3	3	3	3
58	4	2	2	2	3

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=4 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
10	1	1	1	1	1
10	2	1	1	2	1
10	3	1	1	2	1
10	5	1	1	2	1
36	1	1	1	2	2
36	2	2	2	2	3
36	3	2	2	2	2
36	4	2	2	2	2
36	7	3	3	.	2
37	1	3	3	3	3
37	2	2	2	2	.
37	3	1	1	2	.
37	5	1	.	.	.
37	6	2	2	3	2
38	1	1	2	2	2
38	2	2	2	2	1
38	3	2	2	.	2
38	4	1	1	2	1
39	1	2	2	2	2
39	2	2	2	.	2
39	3	1	3	3	3
39	4	1	1	1	1
39	5	2	2	2	1
40	1	2	2	2	2
40	2	1	2	2	2
40	3	1	1	1	1
40	4	1	1	1	1
40	7	1	1	1	1
40	13	2	2	.	3
41	1	2	2	2	3
41	2	3	3	3	3
41	3	2	2	2	2
41	4	2	2	.	3
41	5	2	2	2	2
41	6	1	1	2	2
41	7	2	2	2	3
41	8	2	2	2	2
42	1	1	1	1	1
42	2	2	2	3	.
42	3	2	2	2	3
42	4	2	2	2	3
59	1	2	1	2	1
59	2	2	2	2	3
59	3	1	1	2	1
59	4	2	1	2	1
59	6	2	.	.	.
60	1	2	2	3	3
60	2	1	2	2	1
60	3	1	1	2	2
60	4	2	2	2	2
61	2	1	2	2	1

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=4 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
61	3	1	2	2	1
61	4	2	2	2	2
61	6	1	1	2	1

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=6 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
11	1	1	1	1	1
11	2	1	1	1	2
11	3	1	1	1	1
11	4	2	2	2	1
12	1	2	2	2	.
12	2	1	1	1	.
12	3	1	1	2	.
43	1	2	3	2	2
43	2	3	2	2	3
43	3	1	1	1	1
43	5	1	1	2	2
44	1	2	2	.	.
44	2	3	3	2	.
44	3	2	2	2	.
44	4	2	2	2	.
45	2	2	1	1	3
45	3	2	2	1	3
45	.	1	2	1	2
45	7	2	2	2	2
46	2	1	2	1	2
46	2	1	2	1	2
46	4	2	2	1	2
46	5	2	2	2	3
46	6	2	2	1	3
47	1	2	2	1	3
47	2	2	2	1	2
47	3	2	1	1	3
47	4	3	3	1	3
48	1	2	2	1	3
48	2	2	2	1	2
48	3	3	3	1	3
48	4	2	2	1	2
49	1	2	2	1	3
49	2	1	1	1	1
49	3	3	3	2	3
49	4	2	3	1	3
62	1	2	2	2	3
62	7	1	2	2	3
62	8	2	1	1	2
63	1	2	2	2	3
63	2	2	2	1	2
63	3	2	2	2	3
63	8	2	2	2	3
64	2	2	2	2	.
64	3	1	1	1	.
64	4	2	2	1	.
64	7	1	1	1	.
65	1	2	2	1	2
65	2	2	2	1	2
65	5	2	2	1	2
65	6	2	1	1	1

TABLE A-1. RESPONSE OF RATERS TO OVERALL CONDITION VARIABLE
SEPARATED BY REGION, BUILDING, AND AREA
1=GOOD 2=MODERATE DAMAGE 3=SIGNIFICANT DAMAGE

-- REGION=5 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
66	1	1	1	1	2
66	2	1	1	1	2
66	3	1	1	1	2
66	4	2	1	1	2
66	5	1	1	1	2
66	6	1	1	1	2

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
13	1	1	2	2	3
13	2	3	2	3	3
13	4	2	3	2	3
13	6	3	2	3	3
13	7	3	3	3	3
14	1	2	2	3	3
14	2	2	1	1	1
14	3	2	1	2	1
14	4	2	1	2	3
14	7	2	.	.	.
15	1	2	3	3	.
15	2	2	2	3	.
15	3	3	3	3	.
15	4	2	1	2	.
16	1	2	3	3	3
16	3	3	2	2	3
16	4	3	2	2	3
16	7	3	3	3	3
16	8	3	.	.	.
17	1	2	2	2	3
17	2	2	2	2	3
17	3	3	2	3	3
17	4	3	2	2	3
17	5	2	2	.	.
50	1	3	3	3	3
50	2	2	2	2	3
50	3	2	2	2	3
50	4	2	2	3	3
51	1	2	2	2	3
51	2	2	3	3	3
51	3	2	2	3	3
51	4	1	2	1	3
52	1	2	3	2	3
52	2	2	2	3	3
52	3	2	2	3	3
52	4	1	2	1	2
53	2	3	3	3	3
53	3	3	3	3	3
53	4	3	2	2	3
53	8	2	2	2	3
54	1	2	2	2	3
54	3	3	3	3	3
54	4	3	3	3	3
54	5	3	3	3	3
54	8	3	.	.	.
55	1	2	2	.	2
55	2	3	3	.	3
55	3	3	2	.	3
55	4	2	2	.	3
56	1	2	2	.	3
56	2	2	2	.	3

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
56	3	2	2	.	3
56	4	2	3	.	3
57	1	2	3	3	.
57	2	2	3	2	.
57	4	3	2	2	.
57	5	2	2	2	.
7	1	2	2	2	.
7	2	3	3	3	.
7	3	2	2	2	.
7	4	3	3	3	.
7	7	3	3	.	.
7	8	3	3	.	.
8	1	2	2	2	.
8	2	2	2	2	.
8	3	2	2	2	.
8	4	2	2	2	.

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=2 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
18	1	2	2	3	2
18	2	2	3	3	2
18	3	1	2	2	1
18	4	2	3	3	1
18	8	2	3	3	2
19	1	1	1	1	1
19	2	3	3	3	2
19	3	2	2	3	2
19	4	2	2	3	2
19	7	.	.	.	.
19	8	.	.	.	.
19	9	.	.	.	.
20	1	2	3	3	3
20	2	2	3	2	2
20	3	3	3	3	3
20	4	2	2	3	3
20	5	.	.	.	.
20	8	.	.	.	.
21	1	2	2	3	2
21	2	3	3	3	2
21	3	3	2	3	2
21	4	3	3	2	2
22	1	2	2	3	2
22	2	3	3	2	2
22	3	1	1	1	1
22	4	1	1	2	1
23	1	2	2	2	1
23	2	1	1	2	1
23	3	3	3	3	3
23	4	3	3	3	3
24	1	3	2	3	2
24	2	3	3	3	2
24	4	3	2	3	2
24	5	3	2	3	2
25	1	2	2	1	2
25	2	1	2	1	1
25	3	1	3	1	2
25	4	2	2	1	2
9	1	3	3	2	3
9	2	2	2	3	1
9	3	2	3	3	3
9	4	2	2	3	3

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=3 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
26	1	2	3	3	.
26	2	.	3	3	.
26	3	2	2	1	.
26	4	2	2	1	.
27	1	2	2	2	3
27	2	1	1	1	1
27	3	1	2	1	2
27	4	3	3	2	3
27	8	2	2	2	3
28	1	2	2	1	2
28	2	2	3	2	3
28	3	2	1	2	3
28	4	2	1	3	3
28	5	.	.	.	.
28	6	.	.	.	.
29	1	2	2	2	2
29	2	2	2	1	2
29	3	2	2	2	2
29	4	2	2	1	2
30	1	2	3	2	2
30	3	3	3	.	.
30	4	2	2	1	2
30	6	2	2	2	3
30	8	2	2	1	2
31	1	2	3	2	2
31	2	2	2	2	3
31	3	3	3	2	3
31	4	2	2	2	2
32	1	2	3	3	.
32	2	2	2	1	.
32	4	2	2	1	.
32	6	2	2	1	.
32	9	3	3	3	.
33	1	3	2	2	.
33	4	2	2	2	.
33	5	2	2	2	.
33	9	2	2	2	.
34	1	2	2	2	.
34	2	2	2	3	.
34	3	3	3	3	.
34	4	2	2	3	.
35	1	2	2	3	2
35	2	2	2	2	3
35	3	2	2	1	2
35	4	2	3	2	3
58	1	2	.	1	2
58	2	2	2	1	2
58	3	2	3	2	3
58	4	2	3	2	3

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=4 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
10	1	2	2	.	3
10	2	3	3	3	.
10	3	2	2	2	3
10	5	2	1	3	2
36	1	3	2	2	3
36	2	2	3	2	3
36	3	3	2	2	3
36	4	3	3	3	3
36	7	2	3	3	2
37	1	2	2	3	2
37	2	2	2	2	2
37	3	2	2	2	2
37	5	2	.	.	.
37	6	1	2	2	1
38	1	2	2	2	3
38	2	1	2	2	1
38	3	2	2	3	1
38	4	1	2	2	1
39	1	3	3	2	3
39	2	3	3	3	3
39	3	2	3	3	3
39	4	2	2	1	1
39	5	2	3	2	3
40	1	2	3	2	3
40	2	2	2	3	3
40	3	1	1	1	2
40	4	1	1	2	1
40	7	1	1	2	1
40	13	3	2	3	3
41	1	2	2	2	3
41	2	2	2	3	3
41	3	2	3	2	3
41	4	3	3	3	3
41	5	3	3	3	3
41	6	2	2	2	3
41	7	2	2	3	3
41	8	2	2	3	3
42	1	2	2	2	3
42	2	2	3	3	3
42	3	2	2	2	3
42	4	2	2	2	3
59	1	2	2	2	2
59	2	2	2	2	3
59	3	2	2	2	3
59	4	1	1	2	2
59	6	2	.	.	.
60	1	2	3	3	3
60	2	2	2	2	3
60	3	2	3	3	3
60	4	2	2	2	3
61	2	1	1	3	1

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=4 ---

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
61	3	1	1	3	1
61	4	2	2	3	2
61	6	2	2	3	2

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

--- REGION=5 ---

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
11	1	2	2	1	1
11	2	2	2	1	1
11	3	2	2	1	1
11	4	2	3	2	2
12	1	2	2	1	.
12	2	2	1	1	.
12	3	2	1	1	.
43	1	2	2	1	2
43	2	2	.	1	2
43	3	2	2	1	1
43	5	2	2	2	1
44	1	2	2	1	.
44	2	2	2	2	.
44	3	2	2	2	.
44	4	2	2	1	.
45	2	2	2	1	2
45	3	2	2	1	3
45	4	2	2	1	2
45	7	2	2	1	3
46	2	2	2	1	2
46	2	2	2	1	2
46	4	2	2	1	2
46	5	2	2	1	2
46	6	2	2	1	3
47	1	2	2	1	2
47	2	1	2	1	2
47	3	2	2	1	3
47	4	2	2	1	3
48	1	2	2	1	2
48	2	3	3	1	2
48	3	3	3	1	2
48	4	1	1	1	2
49	1	2	2	1	3
49	2	3	2	1	2
49	3	2	.	1	.
49	4	2	3	1	3
62	1	3	3	3	3
62	7	2	2	2	2
62	8	2	2	1	2
63	1	2	2	2	3
63	2	3	2	1	1
63	3	2	2	1	2
63	8	2	2	1	2
64	2	2	2	1	.
64	3	2	2	1	.
64	4	1	2	1	.
64	7	1	2	1	.
65	1	2	2	1	2
65	2	2	2	1	2
65	5	2	2	1	2
65	6	2	2	1	1

TABLE A-2. RESPONSE OF RATERS TO POTENTIAL FOR DISTURBANCE
SEPARATED BY REGION, BUILDING, AND AREA
1=LOW 2=MODERATE 3=HIGH POTENTIAL

-- REGION=5 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
66	1	1	1	1	1
66	2	1	1	1	1
66	3	1	1	1	.
66	4	1	1	1	1
66	5	1	1	1	1
66	6	1	1	1	1

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
13	1	0	0	0	0
13	2	1	0	1	1
13	4	0	1	0	1
13	6	0	0	0	0
13	7	0	0	0	0
14	1	0	0	0	0
14	2	0	0	0	0
14	3	0	0	0	0
14	4	0	.	0	0
14	7	0	.	.	.
15	1	0	0	0	.
15	2	0	0	0	.
15	3	1	1	1	.
15	4	0	0	0	.
16	1	0	0	0	0
16	3	1	1	1	1
16	4	1	1	1	1
16	7	1	1	0	1
16	8	0	.	.	.
17	1	0	.	0	0
17	2	1	1	1	1
17	3	1	1	0	1
17	4	1	1	0	1
17	5	1	.	.	.
50	1	1	0	0	1
50	2	1	0	0	1
50	3	1	0	0	0
50	4	1	0	0	1
51	1	0	0	0	0
51	2	0	.	1	0
51	3	0	.	0	0
51	4	0	0	0	1
52	1	0	0	0	1
52	2	0	0	0	1
52	3	0	.	0	1
52	4	0	.	0	0
53	2	1	1	1	1
53	3	1	1	1	1
53	4	0	1	1	1
53	8	0	0	0	0
54	1	1	1	0	1
54	3	1	0	0	1
54	4	1	0	0	1
54	5	1	0	0	1
54	8	0	.	.	.
55	1	0	0	.	0
55	2	0	0	.	0
55	3	0	0	.	1
55	4	1	1	.	1
56	1	0	0	.	0
56	2	0	0	.	0

TABLE A-3.RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

-- REGION=1 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
56	3	1	1	.	1
56	4	0	0	.	1
57	1	0	0	0	.
57	2	0	0	0	.
57	4	0	1	1	.
57	5	0	0	0	.
7	1	1	1	0	.
7	2	0	0	0	.
7	3	0	0	1	.
7	4	0	1	0	.
7	7	1	1	.	.
7	8	0	1	.	.
8	1	1	.	0	.
8	2	0	0	0	.
8	3	0	1	0	.
8	4	0	0	0	.

TABLE A-3.RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

REGION=2

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
18	1	1	0	0	1
18	2	1	1	0	0
18	3	0	1	0	0
18	4	0	0	0	0
18	6	0	1	0	0
19	1	1	1	0	0
19	2	0	1	0	0
19	3	0	1	0	0
19	4	0	1	0	0
19	7	.	.	.	.
19	8	.	.	.	.
19	9	.	.	.	.
20	1	1	1	0	1
20	2	0	1	0	0
20	3	1	1	1	1
20	4	0	0	0	0
20	5	.	.	.	.
20	6	.	.	.	.
21	1	0	1	0	0
21	2	0	1	0	0
21	3	0	1	0	0
21	4	0	1	0	0
22	1	0	0	0	0
22	2	0	0	0	0
22	3	0	0	0	0
22	4	0	0	0	0
23	1	0	0	0	0
23	2	0	0	0	0
23	3	1	1	0	0
23	4	1	1	0	1
24	1	0	1	0	0
24	2	0	1	0	0
24	4	0	0	0	0
24	5	1	1	0	0
25	1	1	0	0	0
25	2	0	1	0	0
25	3	1	0	0	0
25	4	1	1	0	0
9	1	1	1	1	1
9	2	0	1	0	0
9	3	0	0	1	0
9	4	0	0	1	1

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

-- REGION=3 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
26	1	1	1	1	.
26	2	1	1	1	.
26	3	0	0	0	.
26	4	0	1	0	.
27	1	0	0	0	0
27	2	0	1	1	0
27	3	0	0	0	0
27	4	0	1	0	0
27	8	0	0	0	0
28	1	0	0	0	0
28	2	0	1	1	0
28	3	0	0	0	0
28	4	1	0	1	1
28	5	.	.	.	.
28	6	.	.	.	.
29	1	0	0	.	0
29	2	1	0	0	0
29	3	0	0	0	0
29	4	0	0	0	0
30	1	0	0	0	0
30	3	1	1	.	.
30	4	1	1	0	1
30	6	0	0	0	0
30	8	1	1	0	1
31	1	0	0	0	0
31	2	0	0	0	0
31	3	1	1	1	1
31	4	0	0	0	0
32	1	1	1	1	.
32	2	0	0	1	.
32	4	0	0	0	.
32	6	0	0	0	.
32	9	0	0	0	.
33	1	.	0	0	.
33	4	0	0	0	.
33	5	0	0	0	.
33	9	0	0	0	.
34	1	0	0	0	.
34	2	0	1	1	.
34	3	.	1	1	.
34	4	0	0	0	.
35	1	1	1	1	1
35	2	1	1	0	0
35	3	0	0	0	0
35	4	1	0	1	0
58	1	0	0	0	0
58	2	0	0	0	1
58	3	0	0	0	0
58	4	0	0	0	0

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

------------------------------ REGION=4 ------------------------------

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
10	1	0	0	0	0
10	2	1	0	0	0
10	3	0	0	0	0
10	5	0	0	0	0
36	1	0	0	0	0
36	2	0	0	0	0
36	3	0	0	0	0
36	4	1	1	1	1
36	7	0	0	0	0
37	1	0	0	0	0
37	2	1	0	0	0
37	3	1	0	0	0
37	5	0	.	.	.
37	6	0	0	0	0
38	1	0	0	0	0
38	2	0	0	0	0
38	3	0	0	0	0
38	4	0	0	0	0
39	1	1	.	1	1
39	2	0	0	.	0
39	3	0	0	0	0
39	4	0	0	0	0
39	5	0	0	0	0
40	1	1	0	0	0
40	2	1	0	0	0
40	3	0	0	0	0
40	4	.	0	0	0
40	7	0	0	0	0
40	13	0	0	0	0
41	1	1	0	0	0
41	2	1	0	0	0
41	3	1	0	0	0
41	4	1	1	1	1
41	5	1	1	1	1
41	6	0	0	0	0
41	7	0	0	0	0
41	8	0	0	0	0
42	1	0	0	1	0
42	2	1	1	1	0
42	3	1	1	1	1
42	4	1	1	1	1
59	1	0	0	0	0
59	2	0	0	0	0
59	3	0	0	0	0
59	4	1	0	1	0
59	6	0	.	.	.
60	1	0	0	0	0
60	2	1	0	0	0
60	3	0	0	0	0
60	4	0	0	0	0
61	2	0	0	0	0

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

REGION=4

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
61	3	0	0	0	0
61	4	1	0	1	0
61	6	0	0	0	0

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW
SEPARATED BY REGION, BUILDING, AND AREA
0=NO AIR FLOW 1=AIR FLOW

-- REGION=5 --

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
11	1	1	0	0	0
11	2	1	0	0	0
11	3	0	0	0	0
11	4	0	0	0	1
12	1	0	0	0	.
12	2	0	0	0	.
12	3	0	0	0	.
43	1	0	0	0	0
43	2	0	0	0	0
43	3	0	0	0	0
43	5	0	0	0	0
44	1	0	0	0	.
44	2	0	0	0	.
44	3	0	0	0	.
44	4	0	0	0	.
45	2	0	0	0	1
45	3	0	0	0	1
45	4	0	0	0	1
45	7	0	0	0	1
46	2	0	0	0	0
46	2	0	0	0	0
46	4	0	0	0	1
46	5	0	0	0	0
46	6	0	0	0	0
47	1	0	0	0	1
47	2	1	0	0	1
47	3	0	0	0	1
47	4	0	0	0	1
48	1	0	0	0	1
48	2	1	0	0	1
48	3	1	0	0	1
48	4	1	.	0	.
49	1	0	0	0	0
49	2	1	0	0	0
49	3	0	0	.	0
49	4	0	0	0	0
62	1	0	0	0	0
62	7	0	0	0	1
62	8	0	0	0	0
63	1	0	0	0	0
63	2	1	0	0	0
63	3	0	0	0	0
63	8	0	0	0	0
64	2	0	0	0	.
64	3	0	0	0	.
64	4	0	0	0	.
64	7	0	0	0	.
65	1	0	0	0	0
65	2	0	0	0	0
65	5	0	0	0	0
65	6	0	0	0	0

TABLE A-3. RESPONSE OF RATERS TO AIR FLOW SEPARATED BY REGION, BUILDING, AND AREA

0=NO AIR FLOW 1=AIR FLOW

REGION=5

BUILDING	AREA	CORE RATER ONE	CORE RATER TWO	LOCAL RATER ONE	LOCAL RATER TWO
66	1	0	0	0	0
66	2	0	0	0	0
66	3	0	0	0	0
66	4	0	0	0	0
66	5	0	0	0	0
66	6	0	0	0	0

APPENDIX B

COUNTS OF THE RESPONSES OF THE RATERS IN EACH ASSESSED AREA WITHIN EACH REGION FOR CONDITION, POTENTIAL FOR DISTURBANCE, AND AIR FLOW FACTORS

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
13	1	2	2	.
	2	.	1	3
	4	2	2	.
	6	.	.	4
	7	.	.	4
14	1	.	.	4
	2	4	.	.
	3	3	1	.
	4	.	3	1
	7	.	.	1
15	1	.	2	1
	2	.	1	2
	3	.	1	2
	4	.	1	2
16	1	.	1	3
	3	.	2	2
	4	.	4	.
	7	.	.	4
	8	.	1	.
17	1	.	4	.
	2	.	3	1

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
17	3	.	3	1
	4	.	3	1
	5	2	.	.
50	1	.	2	2
	2	.	3	1
	3	.	3	1
	4	.	3	1
51	1	.	3	1
	2	.	1	3
	3	.	.	4
	4	4	.	.
52	1	.	1	3
	2	.	2	2
	3	.	1	3
	4	2	2	.
53	2	.	1	2
	3	.	1	3
	4	1	3	.
	8	.	3	1
54	1	.	3	1
	3	.	.	4

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
54	4	.	1	2
	5	.	1	2
	8	.	.	1
55	1	3	.	.
	2	.	3	.
	3	.	1	2
	4	.	.	3
56	1	.	1	1
	2	.	1	1
	3	.	2	1
	4	.	2	1
57	1	.	1	2
	2	.	1	2
	4	2	1	.
	5	1	2	.
7	1	1	2	.
	2	.	3	.
	3	3	.	.
	4	.	.	3
	7	.	.	2
	8	.	.	2

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
8	1	.	3	.
	2	2	1	.
	3	1	2	.
	4	1	2	.

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
18	1	3	.	.
	2	.	2	2
	3	.	4	.
	4	3	1	.
	6	.	2	2
19	1	2	2	.
	2	.	.	4
	3	.	1	3
	4	.	4	.
	7	.	1	.
	8	.	.	1
	9	.	.	1
20	1	.	1	3
	2	.	1	3
	3	3	1	.
	4	.	3	1
	5	.	.	1
	6	.	.	1
21	1	1	2	.
	2	.	.	4
	3	.	3	1

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
21	4	.	4	.
22	1	.	3	1
	2	.	.	4
	3	4	.	.
	4	.	4	.
23	1	4	.	.
	2	.	3	1
	3	.	4	.
	4	.	.	4
24	1	.	1	3
	2	.	1	2
	4	.	.	4
	5	.	4	.
25	1	4	.	.
	2	.	3	.
	3	3	1	.
	4	.	2	2
9	1	1	3	.
	2	4	.	.
	3	.	3	.
	4	.	1	3

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
26	1	.	2	1
	2	.	3	.
	3	.	3	.
	4	1	2	.
27	1	.	1	3
	2	2	1	1
	3	.	4	.
	4	.	.	4
	8	.	3	1
28	1	1	2	1
	2	1	2	1
	3	2	2	.
	4	3	1	.
	5	1	.	.
	6	.	1	.
29	1	.	2	2
	2	.	3	1
	3	.	3	1
	4	1	3	.
30	1	.	2	2
	3	.	.	2

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
30	4	.	4	.
	6	.	2	2
	8	.	2	2
31	1	.	1	3
	2	.	3	1
	3	.	2	2
	4	.	1	3
32	1	.	.	3
	2	1	2	.
	4	.	3	.
	6	1	2	.
	9	.	1	2
33	1	.	1	2
	4	.	3	.
	5	.	1	2
	9	.	3	.
34	1	.	1	2
	2	2	1	.
	3	.	2	1
	4	.	3	.
35	1	2	2	.

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
35	2	4	.	.
	3	.	3	.
	4	.	2	2
38	1	.	3	1
	2	.	1	3
	3	.	.	4
	4	.	3	1

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
10	1	4	.	.
	2	3	1	.
	3	3	1	.
	5	3	1	.
36	1	2	2	.
	2	.	3	1
	3	.	4	.
	4	.	4	.
	7	.	1	2
37	1	.	.	4
	2	.	3	.
	3	2	1	.
	5	1	.	.
	6	.	3	1
38	1	1	3	.
	2	1	3	.
	3	.	3	.
	4	3	1	.
39	1	.	4	.
	2	.	3	.
	3	1	.	3

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
39	4	4	.	.
	5	1	3	.
40	1	.	4	.
	2	1	3	.
	3	4	.	.
	4	4	.	.
	7	4	.	.
	13	.	2	1
41	1	.	3	1
	2	.	.	4
	3	.	4	.
	4	.	2	1
	5	.	4	.
	6	2	2	.
	7	.	3	1
	8	.	4	.
42	1	4	.	.
	2	.	2	1
	3	.	3	1
	4	.	3	1
59	1	2	2	.

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
59	2	.	3	1
	3	3	1	.
	4	2	2	.
	6	.	1	.
60	1	.	2	2
	2	2	2	.
	3	2	2	.
	4	.	4	.
61	2	2	2	.
	3	2	2	.
	4	.	4	.
	6	3	1	.

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
11	1	4	.	.
	2	3	1	.
	3	4	.	.
	4	1	3	.
12	1	.	3	.
	2	3	.	.
	3	2	1	.
43	1	.	3	1
	2	.	2	2
	3	4	.	.
	5	2	2	.
44	1	.	2	.
	2	.	1	2
	3	.	3	.
	4	.	3	.
45	2	2	1	1
	3	1	2	1
	4	2	2	.
	7	.	4	.
46	2	3	2	.
	4	1	3	.

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
46	5	.	3	1
	6	1	2	1
47	1	1	2	1
	2	1	3	.
	3	2	1	1
	4	1	.	3
48	1	1	2	1
	2	1	3	.
	3	1	.	3
	4	1	3	.
49	1	1	2	1
	2	4	.	.
	3	.	1	3
	4	1	1	2
62	1	.	3	1
	7	1	2	1
	8	2	2	.
63	1	.	3	1
	2	1	3	.
	3	.	3	1
	8	.	3	1

TABLE B-1. RESPONSES OF RATERS TO OVERALL CONDITION VARIABLE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		CONDITION		
		GOOD	MODERATE	SIGNIFICANT
		COUNT	COUNT	COUNT
BUILDING	AREA			
64	2	.	3	.
	3	3	.	.
	4	1	2	.
	7	3	.	.
65	1	1	3	.
	2	1	3	.
	5	1	3	.
	6	3	1	.
66	1	3	1	.
	2	3	1	.
	3	3	1	.
	4	2	2	.
	5	3	1	.
	6	3	1	.

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
13	1	1	2	1
	2	.	1	3
	4	.	2	2
	6	.	1	3
	7	.	.	4
14	1	.	2	2
	2	3	1	.
	3	2	2	.
	4	1	2	1
	7	.	1	.
15	1	.	1	2
	2	.	2	1
	3	.	.	3
	4	1	2	.
16	1	.	1	3
	3	.	2	2
	4	.	2	2
	7	.	.	4
	8	.	.	1
17	1	.	3	1
	2	.	3	1

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
17	3	.	1	3
	4	.	2	2
	5	.	2	.
50	1	.	.	4
	2	.	3	1
	3	.	3	1
	4	.	2	2
51	1	.	3	1
	2	.	1	3
	3	.	2	2
	4	2	1	1
52	1	.	2	2
	2	.	2	2
	3	.	2	2
	4	2	2	.
53	2	.	.	4
	3	.	.	4
	4	.	2	2
	8	.	3	1
54	1	.	3	1
	3	.	.	4

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
54	4	.	.	4
	5	.	.	4
	8	.	.	1
55	1	.	3	.
	2	.	.	3
	3	.	1	2
	4	.	2	1
56	1	.	2	1
	2	.	2	1
	3	.	2	1
	4	.	1	2
57	1	.	1	2
	2	.	2	1
	4	.	2	1
	5	.	3	.
7	1	.	3	.
	2	.	.	3
	3	.	3	.
	4	.	.	3
	7	.	.	2
	8	.	.	2

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
8	1	.	3	.
	2	.	3	.
	3	.	3	.
	4	.	3	.

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
18	1	.	3	1
	2	.	2	2
	3	2	2	.
	4	1	1	2
	8	.	2	2
19	1	4	.	.
	2	.	1	3
	3	.	3	1
	4	.	3	1
	7	1	.	.
	8	1	.	.
	9	.	1	.
20	1	.	1	3
	2	.	3	1
	3	.	.	4
	4	.	2	2
	5	.	1	.
	8	.	1	.
21	1	.	3	1
	2	.	1	3
	3	.	2	2

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
21	4	.	2	2
22	1	.	3	1
	2	.	2	2
	3	4	.	.
	4	3	1	.
23	1	1	3	.
	2	3	1	.
	3	.	.	4
	4	.	.	4
24	1	.	2	2
	2	.	1	3
	4	.	2	2
	5	.	2	2
25	1	1	3	.
	2	3	1	.
	3	2	1	1
	4	1	3	.
9	1	.	1	3
	2	1	2	1
	3	.	1	3
	4	.	2	2

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
26	1	.	1	2
	2	.	.	2
	3	1	2	.
	4	1	2	.
27	1	.	3	1
	2	4	.	.
	3	2	2	.
	4	.	1	3
	8	.	3	1
28	1	1	3	.
	2	.	2	2
	3	1	2	1
	4	1	1	2
	5	1	.	.
	6	.	1	.
29	1	.	4	.
	2	1	3	.
	3	.	4	.
	4	1	3	.
30	1	.	3	1
	3	.	.	2

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
30	4	1	3	.
	6	.	3	1
	8	1	3	.
31	1	.	3	1
	2	.	3	1
	3	.	1	3
	4	.	4	.
32	1	.	1	2
	2	1	2	.
	4	1	2	.
	6	1	2	.
	9	.	.	3
33	1	.	2	1
	4	.	3	.
	5	.	3	.
	9	.	3	.
34	1	.	3	.
	2	.	2	1
	3	.	.	3
	4	.	2	1
35	1	.	3	1

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
36	2	.	3	1
	3	1	3	.
	4	.	2	2
58	1	1	2	.
	2	1	3	.
	3	.	2	2
	4	.	2	2

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
10	1	.	2	1
	2	.	.	3
	3	.	3	1
	5	1	2	1
36	1	.	2	2
	2	.	2	2
	3	.	2	2
	4	.	.	4
	7	.	2	2
37	1	.	3	1
	2	.	4	.
	3	.	4	.
	5	.	1	.
	6	2	2	.
38	1	.	3	1
	2	2	2	.
	3	1	2	1
	4	2	2	.
39	1	.	1	3
	2	.	.	4
	3	.	1	3

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
39	4	2	2	.
	5	.	2	2
40	1	.	2	2
	2	.	2	2
	3	3	1	.
	4	3	1	.
	7	3	1	.
	13	.	1	3
41	1	.	3	1
	2	.	2	2
	3	.	2	2
	4	.	.	4
	5	.	.	4
	6	.	3	1
	7	.	2	2
	8	.	2	2
42	1	.	3	1
	2	.	1	3
	3	.	3	1
	4	.	3	1
59	1	.	4	.

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
59	2	.	3	1
	3	.	3	1
	4	2	2	.
	6	.	1	.
60	1	.	1	3
	2	.	3	1
	3	.	1	3
	4	.	3	1
61	2	3	.	1
	3	3	.	1
	4	.	3	1
	6	.	3	1

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 6

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
11	1	2	2	.
	2	2	2	.
	3	2	2	.
	4	.	3	1
12	1	1	2	.
	2	2	1	.
	3	2	1	.
43	1	1	3	.
	2	1	2	.
	3	2	2	.
	5	1	3	.
44	1	1	2	.
	2	.	3	.
	3	.	3	.
	4	1	2	.
45	2	1	3	.
	3	1	2	1
	4	1	3	.
	7	1	2	1
46	2	1	4	.
	4	1	3	.

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 6

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
46	5	1	3	.
	6	1	2	1
47	1	1	3	.
	2	2	2	.
	3	1	2	1
	4	1	2	1
48	1	1	3	.
	2	1	1	2
	3	1	1	2
	4	3	1	.
49	1	1	2	1
	2	1	2	1
	3	1	1	.
	4	1	1	2
62	1	.	.	4
	7	.	4	.
	8	1	3	.
63	1	.	3	1
	2	2	1	1
	3	1	3	.
	8	1	3	.

TABLE B-2. RESPONSES OF RATERS TO POTENTIAL FOR DISTURBANCE, SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		DISTURBANCE		
		LOW	MODERATE	HIGH
		COUNT	COUNT	COUNT
BUILDING	AREA			
64	2	1	2	.
	3	1	2	.
	4	2	1	.
	7	2	1	.
65	1	1	3	.
	2	1	3	.
	5	1	3	.
	6	2	2	.
68	1	4	.	.
	2	4	.	.
	3	3	.	.
	4	4	.	.
	5	4	.	.
	6	4	.	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
13	1	4	.
	2	1	3
	4	2	2
	6	4	.
	7	4	.
14	1	4	.
	2	4	.
	3	4	.
	4	3	.
	7	1	.
15	1	3	.
	2	3	.
	3	.	3
	4	3	.
16	1	4	.
	3	.	4
	4	.	4
	7	1	3
	8	1	.
17	1	3	.
	2	.	4

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
17	3	1	3
	4	1	3
	5	.	1
50	1	2	2
	2	2	2
	3	3	1
	4	2	2
51	1	4	.
	2	2	1
	3	3	.
	4	3	1
52	1	3	1
	2	3	1
	3	2	1
	4	3	.
53	2	.	4
	3	.	4
	4	1	3
	8	4	.
54	1	1	3
	3	2	2

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
54	4	2	2
	5	2	2
	8	1	.
55	1	3	.
	2	3	.
	3	2	1
	4	.	3
56	1	3	.
	2	3	.
	3	.	3
	4	2	1
57	1	3	.
	2	3	.
	4	1	2
	5	3	.
7	1	1	2
	2	3	.
	3	2	1
	4	2	1
	7	.	2
	8	1	1

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 1

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
8	1	1	1
	2	3	.
	3	2	1
	4	3	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
18	1	2	2
	2	2	2
	3	3	1
	4	4	.
	8	3	1
19	1	2	2
	2	3	1
	3	3	1
	4	3	1
	7	1	.
	8	1	.
	9	1	.
20	1	1	3
	2	3	1
	3	.	4
	4	4	.
	5	.	1
	8	.	1
21	1	3	1
	2	3	1
	3	3	1

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 2

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
21	4	3	1
22	1	4	.
	2	4	.
	3	4	.
	4	4	.
23	1	4	.
	2	4	.
	3	2	2
	4	1	3
24	1	3	1
	2	3	1
	4	4	.
	5	2	2
25	1	3	1
	2	3	1
	3	3	1
	4	2	2
9	1	.	4
	2	3	1
	3	3	1
	4	2	2

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
26	1	.	3
	2	.	3
	3	3	.
	4	2	1
27	1	4	.
	2	2	2
	3	4	.
	4	3	1
	8	4	.
28	1	4	.
	2	2	2
	3	4	.
	4	1	3
	5	1	.
	6	1	.
29	1	3	.
	2	3	1
	3	4	.
	4	4	.
30	1	4	.
	3	.	2

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
30	4	1	3
	6	4	.
	8	1	3
31	1	4	.
	2	4	.
	3	.	4
	4	4	.
32	1	.	3
	2	2	1
	4	3	.
	6	3	.
	9	3	.
33	1	2	.
	4	3	.
	5	3	.
	9	3	.
34	1	3	.
	2	1	2
	3	.	2
	4	3	.
35	1	.	4

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 3

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
35	2	2	2
	3	4	.
	4	2	2
68	1	4	.
	2	3	1
	3	4	.
	4	4	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
10	1	4	.
	2	3	1
	3	4	.
	5	4	.
36	1	4	.
	2	4	.
	3	4	.
	4	.	4
	7	4	.
37	1	4	.
	2	3	1
	3	3	1
	5	1	.
	6	4	.
38	1	4	.
	2	4	.
	3	4	.
	4	4	.
39	1	.	3
	2	3	.
	3	4	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW, SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
39	4	4	.
	5	4	.
40	1	3	1
	2	3	1
	3	4	.
	4	3	.
	7	4	.
	13	4	.
41	1	3	1
	2	3	1
	3	3	1
	4	.	4
	5	.	4
	6	4	.
	7	4	.
	8	4	.
42	1	3	1
	2	1	3
	3	.	4
	4	.	4
59	1	4	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 4

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
59	2	4	.
	3	4	.
	4	2	2
	6	1	.
60	1	4	.
	2	3	1
	3	4	.
	4	4	.
61	2	4	.
	3	4	.
	4	2	2
	6	4	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
11	1	3	1
	2	3	1
	3	4	.
	4	3	1
12	1	3	.
	2	3	.
	3	3	.
43	1	4	.
	2	4	.
	3	4	.
	5	4	.
44	1	3	.
	2	3	.
	3	3	.
	4	3	.
45	2	3	1
	3	3	1
	4	3	1
	7	3	1
46	2	5	.
	4	3	1

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
46	5	4	.
	6	4	.
47	1	3	1
	2	2	2
	3	3	1
	4	3	1
48	1	3	1
	2	2	2
	3	2	2
	4	1	1
49	1	4	.
	2	3	1
	3	3	.
	4	4	.
62	1	4	.
	7	3	1
	8	4	.
63	1	4	.
	2	3	1
	3	4	.
	8	4	.

TABLE B-3. RESPONSES OF RATERS TO AIR FLOW,
SEPARATED BY REGION, BUILDING AND AREA.

REGION 5

		AIR FLOW	
		NO	YES
		COUNT	COUNT
BUILDING	AREA		
64	2	3	.
	3	3	.
	4	3	.
	7	3	.
65	1	4	.
	2	4	.
	5	4	.
	6	4	.
66	1	4	.
	2	4	.
	3	4	.
	4	4	.
	5	4	.
	6	4	.

APPENDIX C

CLASSIFICATION OF ACM CONDITION
(USEPA 1986a)

SURFACING MATERIAL

Significant Damage -- ACM with one or more of the following characteristics: the surface crumbling or blistered over at least one tenth of the area if the damage is evenly distributed, or at least one quarter if the damage is localized; large areas of material hanging from the surface, delaminated, or showing adhesive failure; at least one tenth of the surface water-stained or heavily gouged, marred or abraded (or one quarter if the damage is localized); large accumulation of powder, dust, or debris on surfaces beneath the ceiling or wall.

Moderate Damage -- ACM with one or more of the following characteristics: up to one tenth of the surface (if the damage is evenly distributed) or up to one quarter of the surface (if the damage is localized) blistered, crumbling, water-stained, or gouged, marred or abraded; some accumulation of powder, dust or debris on surfaces beneath the ceiling or wall.

Good Condition -- ACM with no visible damage or deterioration, or showing only very limited damage or deterioration.

THERMAL SYSTEM INSULATION

Significant Damage -- ACM with one or more of the following characteristics: mostly missing jackets; water-damaged, crushed or heavily gouged or punctured insulation on at least one tenth of pipe runs/risers if the damage is evenly distributed, or at least one quarter if the damage is localized; powder, dust, and debris on surfaces beneath pipe/boilers/tanks, etc.

Moderate Damage -- ACM with one or more of the following characteristics: a few water stains or sections of missing jackets; crushed insulation or water stains, gouges, punctures, or mars on up to one tenth of the insulation if the damage is evenly distributed, or up to one quarter if the damage is localized; some accumulation of powder, dust, debris on surfaces beneath pipes/boilers/tanks, etc.

Good Condition -- ACM with no visible damage or deterioration, or showing only very limited damage or deterioration.

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APPENDIX D

AIR SAMPLING FIELD METHODS

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Asbestos air samples were collected on 0.45 µm pore size, cellulose acetate membrane filters enclosed in preassembled 37 mm cassettes. Two side-by-side samples were collected at each location, each at a different flow rate. Volumes were controlled through the use of two limiting orifices, 5.0 lpm, and 2.5 lpm, with air flow being drawn across the filter by a diaphragm vacuum pump. Collection of side-by-side samples at two different flow rates allowed for a backup filter, should the higher flow rate sample become overloaded. Samples were logged in the field and hand carried to the analytical laboratory.

A. Site Selection

Sampling locations in each of the monitored buildings were based on the representativeness of the location, proximity to the ACM, accessibility, potential for vandalism, and access to power. In general, eight sampling locations were selected in each of the monitored buildings: seven indoor locations and one outdoor ambient location.

Pump placement involved locating two pumps directly in the area with the most damaged ACM, 2 in the nearest public access area, 2 in other assessed areas, one in a public access area adjacent to another area; and one pump at an outdoor location. Local circumstances may have required pump placement at other sites in a few instances.

In general, a sampling survey in each study region was split into two segments, with each segment involving sample collection in 5 buildings. The exception to this was Study Region 4, consisting of 2 cities, in which 5 buildings were sampled in each city. Each sampling period contained an initial set-up day for pump placement, a 2-day sampling period, and approximately one day for breakdown and filter delivery.

B. Sampling Equipment

The sampling system used during the project consisted of the following:

- Two open-faced 37 mm cassettes, each containing a 0.4 µm cellulose acetate membrane filter;
- Two flow control orifices; one at 2.5 lpm and the other at 5 lpm;
- A pump with a muffler;
- Associated plumbing and stand;

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- A 7-day timer; and

- A clock to record elapsed time.

The sampler setup is represented in Figure D-1 with two modifications. The 36-inch rod used to hold the filters in place was attached to a separate laboratory stand and not to the pump base. This modification served to minimize the effects of pump vibrations on the filter. The second modification was the use of a T-fitting with two orifices (5.0 lpm and 2.5 lpm) and two separate filter cassettes. This allowed for the collection of two simultaneous samples, each at a different flow rate.

C. Sample Collection Procedures

Sample collection in each building was conducted during periods of maximum activity (daylight hours) over a 2-day period. Generally, sample collection hours were between 7:00 a.m. and 5:00 p.m. on each day of the 2-day sampling period. Exceptions occurred when timer malfunctions required alterations of the sampling period.

Pumps were set up one day prior to the actual sample collection and set to activate the morning of the following day via an in-line, 7-day timer. Advance set-up was necessary to ensure that all samples started at approximately the same time each day, since geographic locations were dispersed and building access in the early morning hours uncertain. The following details the sampling procedures followed during the program.

Sampling Protocol

1. Visually inspect preloaded filter cassettes for damage. Label filter cassette with random I.D.;

2. Place filter in cassette holder, clamp into position, and attach pump tubing. Ensure that filter holder (ring stand) is placed in such a way as to minimize or eliminate vibration effects caused by the pump;

3. Rotate filter holders to a vertical position (perpendicular to the ground);

4. Check plumbing for any leaks;

5. Check flow rates with a flowmeter;

6. Set automatic timer to correct date and time;

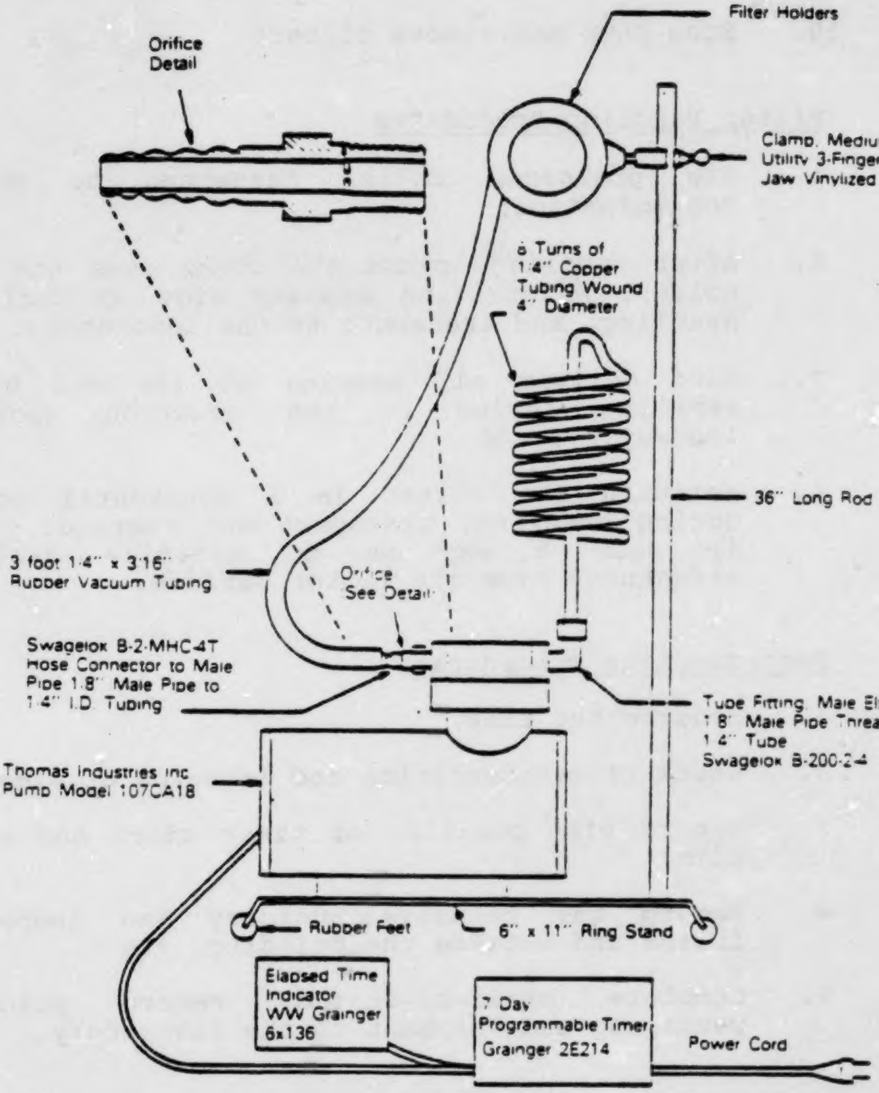

Filter Holders
Orifice Detail
Clamp, Medium Utility 3-Finger Jaw Vinylized
6 Turns of 1/4" Copper Tubing Wound 4" Diameter
36" Long Rod
3 foot 1/4" x 3/16" Rubber Vacuum Tubing
Orifice See Detail
Swagelok B-2-MHC-4T Hose Connector to Male Pipe 1/8" Male Pipe to 1/4" I.D. Tubing
Tube Fitting, Male Elbow 90° 1/8" Male Pipe Threaded to 1/4" Tube Swagelok B-200-2-4
Thomas Industries Inc Pump Model 107CA18
Rubber Feet
6" x 11" Ring Stand
Elapsed Time Indicator WW Grainger 6x136
7 Day Programmable Timer Grainger 2E214
Power Cord

Figure D-1. Pump diagram.

7. Make appropriate logbook entries;
8. Conduct sampling;
9. After sampling, check flows (leave pump running); and
10. Stop pump and remove filters.

Filter Handling Procedures

1. Use preloaded filter cassettes to minimize contamination;
2. After sampling, place the cover over the filter holder, maintaining exposed side up during the handling, and transport to the laboratory;
3. Hand deliver all samples at the end of each sampling period to the electron microscopy laboratory; and
4. Maintain the filter in a horizontal position during handling, transport and storage. Handle in such a way as to minimize dislodging structures from the filter surface.

Post-Sampling Procedures

1. Measure the flow;
2. Check filter condition and location of sampler;
3. Record time position of timer clock and elapsed time;
4. Record the relative humidity and temperature inside and outside the building; and
5. Complete chain-of-custody record prior to packaging and shipment to the laboratory.

Logbook/Data Form Entries

An important part of any field program are the observations and accurate records of the field team. The following information was recorded in the logbook and data forms for each sampling location:

1. Name of field program;
2. Date of record;
3. Site number and location;
4. Tag numbers of pump and timer;
5. Relative humidity and temperature inside and outside the building;
6. Position of sampler within the site;
7. Brief site description;
8. Corresponding filter number;
9. Sample flow rate at the start of sampling;
10. Settings of timer clock;
11. Sample flow rate at end of sampling period;
12. Comments; and
13. Name(s) of samplers.

A copy of the data form used during this program is included as Figure D-2.

Field Flow Measurement

At a minimum, flow rate measurements were taken twice during a sample run: during sampler set up prior to initiation of the run, and at the completion of sampling. If possible, a mid-point flow measurement also was taken. The following describes the procedures used to determine sample flow rates in the field.

1. Turn on the sampling pump;
2. Set up the sampling system as shown below with both rotameters in line between the filter and the orifice;

Field Data Sheet

Project No. __________ Start Date __________ Stop Date ________

Building I.D. ____

____

Location ____

____

Pump I.D. No. __________ Flow Control Device __________________

Filter Lot #. ____________ Type __________________

Box #. __________________

Random I.D. #. ______________

Day 1:

Start ________ Stop ________ Elapsed ______

Day 2:

Start ________ Stop ________ Elapsed ______

Flow Checks:

Date __________ Temp. __________ B.P. ________ V.P. ________

Time __________ Rotameter Reading ________ Rotameter No. __________

Flow Rate (stp) __________

Date __________ Temp. __________ B.P. ________ V.P. ________

Time __________ Rotameter Reading ________ Rotameter No. __________

Flow Rate (stp) __________

Date __________ Temp. __________ B.P. ________ V.P. ________

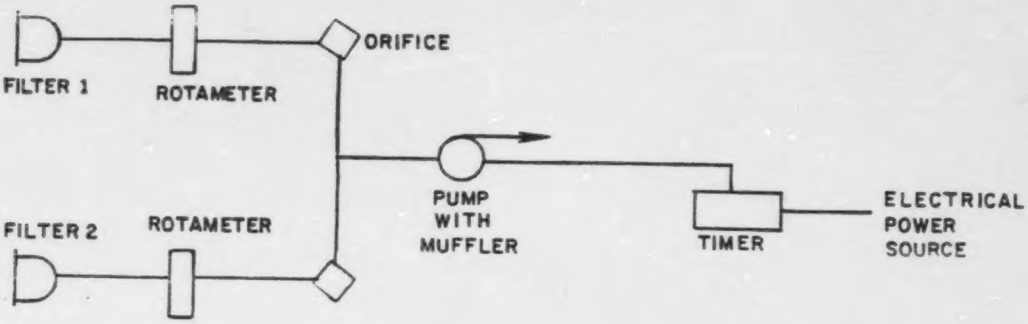
Time __________ Rotameter Reading ________ Rotameter No. __________

Flow Rate (stp) __________

Picture Roll # ________ Frame # ________

Comments:

Figure D-2. Field data form used for air monitoring.


ORIFICE
FILTER 1
ROTAMETER
PUMP WITH MUFFLER
TIMER
ELECTRICAL POWER SOURCE
FILTER 2
ROTAMETER

3. Record the rotameter readings in the notebook;
4. Turn off the pump and remove the rotameters;
5. Reconnect all tubing and turn the filters to a horizontal position;
6. Repeat procedures 1 through 5 at the end of the sampling period; and
7. Calculate the flow as follows:
    a. Using the calibration curve for the rotameter, determine the flow rates for each rotameter reading and record these values on the data sheet.
    b. Calculate the average flow rate for the sampling period using the following equation:

$$\text{Average flow rate} = \frac{(\text{initial flow rate} + \text{final flow rate})}{2}$$

    c. Calculate the actual volume of sample collected by multiplying the average sample rate by the sampling time.

APPENDIX E

AIR SAMPLE PREPARATION AND SUMMARY OF TEM ANALYTICAL PROTOCOL

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SAMPLE PREPARATION

The following is an abbreviated version of the sample preparation procedure utilized in this project. A more detailed version of the procedure, along with the references related to the development of this procedure, is contained in Section 7 of Yamate et al. (1984).

The Low Temperature Asher (LTA) used in these tests was calibrated through a series of tests to determine the etching rate of a mixed cellulose ester filter. It was the intent of this project to etch approximately 1 μm of the surface to reveal structure detail that may have been hidden in the replicate.

Procedure:

1. A section of the membrane filter is cut with a scalpel, and placed on a clean microscope slide with the sampled side facing up.
2. The cut section is fastened on all sides to the slide with narrow strips of transparent tape.
3. The slide, with the cut section, is exposed to acetone vapor (not liquid) for approximately 10 minutes. The acetone vapor collapses the structure of the filter and produces a fused, relatively smooth-surfaced film. The size of the acetone vapor bath and time of filter response to the vapors are critical in obtaining the desired smooth, fused surface.
4. Each collapsed filter segment with a known deposit area is carefully placed in a clean test tube (13 mm x 80 mm) using a clean tweezer.
5. With forceps, the tubes containing the sample, and 1 lab blank (unused filter segment of the same size and type of filter material as the sample) are placed lengthwise, side by side in the chamber, with the mouths of the tubes facing the open end (door) of the asher chamber. The tubes are laid in the center of the chamber within the region of the coils surrounding the chamber. Up to four sample tubes and 1 blank can be laid like logs inside the chamber.
6. The power is slowly and carefully increased to prevent "flashing" of the filter, which would result in loss of sample.
7. The filter membrane is etched for approximately 30 seconds. The chamber is slowly allowed to reach ambient pressure.

8. The etched-collapsed filter section is placed on the rotating stage of the vacuum evaporator for carbon-coating.

9. A 3-mm-diameter portion of the carbon-coated filter is transferred to an EM grid in the modified Jaffe wick washer.

10. Acetone is used in dissolving the fused membrane filter.

11. Transfer to the properly labeled grid storage container.

SUMMARY OF TEM ANALYTICAL PROTOCOL

The following is a summary of the Analytical Protocol utilized in this project. A more detailed description of the protocol is contained in Appendix B to the Quality Assurance Plan (Hatfield et al. 1987) for this project.

Procedure:

1. Start a new Count Sheet for each sample to be analyzed. Record on that sheet: Client Name; Project or Job No.; Sample No.; Volume of Air Analyzed (from TEM Working Log); Microscope; Magnification for Analysis; Filter type, and Diameter.

2. Start with the grid in capsule labelled No. 1 located in the Specimen Box.

3. Determine Suitability of Grid

    A. Look at grid in Low Mag mode (100X) to determine its suitability for detailed study at higher mags.

    B. Reject grid if:

        i. Replica does not cover at least 15 full grid openings with 0% holes in any grid, and < 15% coverage maximum. Discount any grid opening that is doubled or folded for counting.

        ii. Specimen is too dark due to incomplete dissolution of the filter.

        iii. The average particulate loading exceeds 15%.

    C. If grid is rejected, load grid from capsule No. 2, etc.

    D. If grid is acceptable, continue on to next step.

4. Scan the Grid

   A. Set the magnification to 19,000X

   B. Scan grid as follows:

      i. At the appropriate magnification, make a series of parallel traverses across the grid opening. Traverse the grid opening (also referred to as a field), starting at 1 corner (upper left or upper right) and using the area defined by the small square of the fluorescent screen (area of screen that lifts up for photograph purposes) as a "window".

      ii. On reaching the end of 1 traverse, move the image 1 "window" width, and reverse the traverse. A slight overlap should be used so as not to miss any part of the opening.

      iii. Make parallel traverses until the entire grid opening has been scanned.

   C. Ten good fields or grid openings or 100 structures need to be counted (whichever comes first).

5. Identify each structure morphologically and analyze as it enters the "window".

6. For morphology: appearance and size

   A. Determine morphologically if the structure is a "fiber", "bundle", "cluster", or "matrix".

   B. If record "bundle", "cluster", or "matrix", then record also how many figures are involved; i.e., Bundle 7, Bundle > 50, etc.

   C. Size each structure using the calibrated 20 mm rule on the screen.

7. Selected area electron diffraction pattern (SAED)

   A. Center structure, focus and obtain SAED pattern

   B. From a visual examination of the electron diffraction pattern (camera length (CL) of 22; through binoculars on small screen), classify the observed structure as belonging to one of the following categories by comparing it to known patterns:

i. Chrysotile: The chrysotile asbestos pattern has characteristic streaks on layer lines other than the central line and some streaking also on the central alternate lines (2nd, 4th, etc.). The repeat distance between layer lines is about 0.53 mm.

ii. Amphibole Group (includes amosite, crocidolite, anthophyllite, tremolite and actinolite): Amphibole asbestos structure patterns who layer lines formed by very closely spaced dots, and the repeat distance between layer lines is also about 0.53 mm. Streaking in layer lines is occasionally present due to structure defects.

iii. Ambiguous (incomplete spot patterns).

iv. N, if there is no pattern present. (This should go under SAED column).

C. If the pattern is a suspected chrysotile or amphibole, then take picture of diffraction pattern as needed.

8. X-ray Analysis (EDS).

A. For each structure that chemistry is necessary, take chemistry with EDS system.

B. If EDS signal is weak, take another spectrum, being sure that spot is still on structure.

C. If EDS is used for confirmation, record structure identification. Record a check mark or an "X" in EDS column when chemistry is checked but not saved.

D. If EDS is used in case of unknown or ambiguous structures, categorizing amphiboles or showing representative structures on particular field, save spectra to disk and record Disk No. and File No. on Count Sheet under EDS Column.

9. After all necessary analyses of structure, continue scanning until all structures are identified, measured, analyzed, and categorized in the grid opening.

10. Select additional grid openings at low mag, scan at 19,000X and analyze until the total number of asbestos structures exceeds 100, or a minimum of 10 grid openings have been examined, whichever comes first.

11. Carefully record all data as it is being collected, and check for accuracy.

12. After finishing with grid, remove from microscope,and replace in appropriate polyethylene capsule.

APPENDIX F

ANALYSIS OF TEM GRID OPENING DATA

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BACKGROUND

When air samples are analyzed for asbestos by TEM using a direct preparation technique the spatial distribution of asbestos structures on the electron microscope grid is similar to their distribution on the filter at the time of collection. (Some changes may take place during transport to the laboratory.) Concerns have been raised over the uniformity of the spatial distribution. Since only a small proportion of the filter is examined, a highly clumped or non-uniform distribution may yield low structure counts by chance, even though the average structure density is high. Conversely, if the area of filter examined happens to include an aggregation of asbestos structures the airborne asbestos concentration will be overestimated.

No asbestos structures were detected on over 80% of the samples collected in this study. This prompted additional analyses to determine if the low structure counts reflected actual low airborne asbestos concentrations or could be explained by a non-uniform distribution of asbestos structures on the surface of the filter. The objective of the investigation was to characterize the spatial distribution of asbestos structures and determine the effect of the distribution on the precision of structure counts.

STUDY DESIGN

Sixteen air samples were selected for additional analysis to determine if the 10 grid openings specified by the TEM protocol provide estimates of sufficient precision for the purposes of the study. The 16 samples were selected as follows to provide a range of structure counts:

- 4 "indoor" samples which had structure counts of 3 or more in the first 10 grid openings counted;
- 8 "indoor" samples which had structure counts of 0 in the first 10 grid openings;
- 2 "outdoor" samples; and
- 2 field blanks.

Samples were selected at random within each category.

An additional 40 grid openings, giving a total of 50, were examined on each sample and the number of structures in each opening recorded.

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STATISTICAL MODEL

The negative binomial is a discrete distribution which is often used to describe clumped or aggregated populations. Javitz and Fowler (1981) found that the negative binomial was superior to the Poisson for describing asbestos structure counts obtained by electron microscopy. The variance of the negative binomial is $m(m+k)/k$ where m is the mean and k is a measure of aggregation. As k increases the variance decreases and consequently the precision of estimated airborne asbestos concentrations increases. The Poisson distribution is a limiting case of the negative binomial as k becomes very large.

If the number of asbestos structures in one grid opening is assumed to be distributed according to a negative binomial distribution with parameters m and k, then the number of structures in n grid openings is distributed according to a negative binomial with parameters nm and nk. This result assumes that the number of structures in a grid opening is independent of the number in any other grid opening. The assumption will hold if grid openings are selected at random. If grid openings are not selected at random then one must assume that there is no spatial correlation between the number of structures in different grid openings.

PARAMETER ESTIMATES

The maximum likelihood estimate of m is the sample mean $\bar{x}$. The maximum likelihood estimate of k is obtained by solving the equation

$$n\log(1 + \frac{\bar{x}}{k}) = \sum_{j=1}^{\infty} f_j(1/k + 1/(k+1) + \ldots + 1/(k+j-1)),$$

where f_j is the number of grid openings with j structures (Bishop et al 1975). Estimates of m and k were obtained for each sample. Large values of k mean higher precision, and hence narrower confidence intervals for the total structure count on a filter.

CONFIDENCE INTERVALS

Exact $100(1-\alpha)\%$ confidence intervals, (m_L, m_U), were obtained for $x > 0$ by finding m_L and m_U such that

$$F(x, m_U) = \alpha/2, \text{ and}$$

$$F(x, m_L) = 1-\alpha/2,$$

where $F(x,m)$ is the cumulative distribution function of the negative binomial distribution with mean m. For x=0 the 100(1-

α)% confidence interval is given by $(0,m_U)$ where m_U satisfies $F(x,m_U)=\alpha$.

A negative binomial with parameters nm and nk is used to obtain confidence intervals for the total count on a filter when n grid openings are examined. Increasing k, and/or increasing n, increases the precision of the count and reduces the width of the confidence interval.

RESULTS

No asbestos structures were counted on eight of the 16 filters. The eight include the two field blanks and the two outdoor samples. Of the eight filters with non-zero counts, five have estimates of k equal to infinity. The remaining three estimates of k are 0.6, 0.4, and 0.07.

For $k=\infty$, i.e., a Poisson distribution, a 95% confidence interval for the true structure count when no structures are counted in 10 grid openings is (0,3.0). The size of the confidence interval increases slightly to (0,3.1) as k decreases to 0.4. Thus, for values of k greater than or equal to 0.4 the examination of 10 grid openings in this study yields an airborne asbestos concentration that is sufficiently precise to distinguish 0 s/cc from 0.009 s/cc with high probability. (In this study one structure corresponds to approximately 0.003 s/cc.)

The data indicate that k is usually greater than 0.4, but that smaller values, such as k=0.07 are possible. The standard deviation of this estimate of k is 0.9. For k=0.07, a 95% confidence interval for the true structure count when no structures are counted in 10 grid openings is (0,50). If the number of grid openings counted is increased to 50, the confidence interval shrinks to (0,4.7).

Of the 16 filters examined, all but one indicate that examination of 10 grid openings is sufficient to distinguish 0 s/cc from 0.009 s/cc with high probability. Although, without additional data, it is difficult to predict how frequently exceptions will occur, the results suggest that examination of additional grid openings is generally unnecessary unless higher precision is required.

APPENDIX G

AIR MONITORING DATA LISTING

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TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
------------------------------------------- BUILDING NUMBER =1 BUILDING CATEGORY =1 -----------------------------------

                                            SITE     STRUCTURE
                                                     CONCENTRATION

                                              0              0.000
                                              1              0.001
                                              2              0.000
                                              3              0.000
                                              4              0.000
                                              5              0.000
                                              6              0.000
                                              7              0.000

------------------------------------------- BUILDING NUMBER =2 BUILDING CATEGORY =1 -----------------------------------

                                            SITE     STRUCTURE
                                                     CONCENTRATION

                                              0              0.000
                                              1              0.000
                                              2              0.000
                                              3              0.000
                                              4              0.002
                                              5              0.000
                                              6              0.000
                                              7              0.033

------------------------------------------- BUILDING NUMBER =3 BUILDING CATEGORY =1 -----------------------------------

                                            SITE     STRUCTURE
                                                     CONCENTRATION

                                              0              0.000
                                              1              0.000
                                              2              0.005
                                              3              0.000
                                              4              0.000
                                              5              0.000
                                              6              0.000
                                              7              0.000
```

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TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
-------------------------------------------- BUILDING NUMBER =4 BUILDING CATEGORY =1 ----------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0            0.000
                                                   1            0.000
                                                   2            0.000
                                                   3            0.000
                                                   4            0.000
                                                   5            0.000
                                                   6            0.000
                                                   7            0.000

-------------------------------------------- BUILDING NUMBER =5 BUILDING CATEGORY =1 ----------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0            0.003
                                                   1            0.000
                                                   2            0.000
                                                   3            0.000
                                                   4            0.000
                                                   5            0.000
                                                   6            0.000
                                                   7            0.000

-------------------------------------------- BUILDING NUMBER =6 BUILDING CATEGORY =1 ----------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0            0.000
                                                   1            0.000
                                                   2            0.000
                                                   3            0.000
                                                   4            0.000
                                                   5            0.000
                                                   6            0.000
                                                   7            0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
---------------------------------------- BUILDING NUMBER =7 BUILDING CATEGORY =2 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0             0.000
                                                     1             0.001
                                                     2             0.000
                                                     3             0.000
                                                     4             0.003
                                                     5             0.000
                                                     6             0.003
                                                     7             0.000

---------------------------------------- BUILDING NUMBER =8 BUILDING CATEGORY =2 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0             0.003
                                                     1             0.004
                                                     2             0.000
                                                     3             0.003
                                                     4             0.003
                                                     5             0.000
                                                     6             0.000
                                                     7             0.000

---------------------------------------- BUILDING NUMBER =9 BUILDING CATEGORY =2 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0             0.000
                                                     1             0.003
                                                     2             0.000
                                                     3             0.000
                                                     4             0.000
                                                     5             0.000
                                                     6             0.000
                                                     7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
--------------------------------------------- BUILDING NUMBER =10 BUILDING CATEGORY =2 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.000
                                                   3             0.000
                                                   4             0.000
                                                   5             0.000
                                                   6             0.000
                                                   7             0.000

--------------------------------------------- BUILDING NUMBER =11 BUILDING CATEGORY =2 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.002
                                                   3             0.000
                                                   4             0.000
                                                   5             0.000
                                                   6             0.000
                                                   7             0.000

--------------------------------------------- BUILDING NUMBER =12 BUILDING CATEGORY =2 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.002
                                                   3             0.000
                                                   4             0.000
                                                   5             0.000
                                                   6             0.000
                                                   7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
------------------------------------------ BUILDING NUMBER =13 BUILDING CATEGORY =3 --------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.005
                                                   3             0.004
                                                   4             0.002
                                                   5             0.000
                                                   6             0.006
                                                   7             0.000

------------------------------------------ BUILDING NUMBER =14 BUILDING CATEGORY =3 --------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0             0.000
                                                   1             0.004
                                                   2             0.000
                                                   3             0.000
                                                   4             0.000
                                                   5             0.000
                                                   6             0.000
                                                   7             0.000

------------------------------------------ BUILDING NUMBER =15 BUILDING CATEGORY =3 --------------------------------

                                                  SITE    STRUCTURE
                                                          CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.001
                                                   3             0.003
                                                   4             0.000
                                                   5             0.001
                                                   6             0.000
                                                   7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
--------------------------------------------- BUILDING NUMBER =16 BUILDING CATEGORY =3 ----------------------------------

                                                  SITE     STRUCTURE
                                                           CONCENTRATION

                                                    0              0.000
                                                    1              0.001
                                                    2              0.000
                                                    3              0.002
                                                    4              0.000
                                                    5              0.000
                                                    6              0.000
                                                    7              0.003

--------------------------------------------- BUILDING NUMBER =17 BUILDING CATEGORY =3 ----------------------------------

                                                  SITE     STRUCTURE
                                                           CONCENTRATION

                                                    0              0.000
                                                    1              0.000
                                                    2              0.000
                                                    3              0.000
                                                    4              0.000
                                                    5              0.000
                                                    6              0.000
                                                    7              0.000

--------------------------------------------- BUILDING NUMBER =18 BUILDING CATEGORY =3 ----------------------------------

                                                  SITE     STRUCTURE
                                                           CONCENTRATION

                                                    0              0.000
                                                    1              0.000
                                                    2              0.000
                                                    3              0.000
                                                    4              0.000
                                                    5              0.003
                                                    6              0.003
```

```
TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS
           STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS
           AIR SAMPLED.  THE "0" SITE AT EACH BUILDING IS
           ALWAYS THE OUTDOOR LOCATION.  SITES 1-7 DO NOT
           CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES
           A AND B.

---------------------------------------- BUILDING NUMBER =19 BUILDING CATEGORY =3 ----------------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                               0              0.000
                                               1              0.000
                                               2              0.003
                                               3              0.000
                                               4              0.000
                                               5              0.000
                                               6              0.000
                                               7              0.000

---------------------------------------- BUILDING NUMBER =20 BUILDING CATEGORY =3 ----------------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                               0              0.000
                                               1              0.000
                                               2              0.000
                                               3              0.003
                                               4              0.000
                                               5              0.000
                                               6              0.000
                                               7              0.000

---------------------------------------- BUILDING NUMBER =21 BUILDING CATEGORY =3 ----------------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                               0              0.000
                                               1              0.000
                                               2              0.000
                                               3              0.000
                                               4              0.000
                                               5              0.000
                                               6              0.000
                                               7              0.000
```

```
TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS
           STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS
           AIR SAMPLED.  THE "0" SITE AT EACH BUILDING IS
           ALWAYS THE OUTDOOR LOCATION.  SITES 1-7 DO NOT
           CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES
           A AND B.
-------------------------------------------- BUILDING NUMBER =22 BUILDING CATEGORY =3 ----------------------------------

                                                      SITE    STRUCTURE
                                                              CONCENTRATION

                                                        0          0.000
                                                        1          0.000
                                                        2          0.000
                                                        3          0.000
                                                        4          0.000
                                                        5          0.000
                                                        6          0.000
                                                        7          0.000

-------------------------------------------- BUILDING NUMBER =23 BUILDING CATEGORY =3 ----------------------------------

                                                      SITE    STRUCTURE
                                                              CONCENTRATION

                                                        0          0.000
                                                        1          0.003
                                                        2          0.013
                                                        3          0.000
                                                        4          0.000
                                                        5          0.003
                                                        6           .
                                                        7          0.000

-------------------------------------------- BUILDING NUMBER =24 BUILDING CATEGORY =3 ----------------------------------

                                                      SITE    STRUCTURE
                                                              CONCENTRATION

                                                        0          0.000
                                                        1          0.000
                                                        2          0.000
                                                        3          0.000
                                                        4          0.000
                                                        5          0.000
                                                        6          0.000
                                                        7          0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
--------------------------------------------- BUILDING NUMBER =25 BUILDING CATEGORY =3 ---------------------------------

                                                SITE     STRUCTURE
                                                         CONCENTRATION

                                                  0             0.000
                                                  1             0.000
                                                  2             0.000
                                                  3             0.013
                                                  4             0.000
                                                  5             0.000
                                                  6             0.000
                                                  7             0.000

--------------------------------------------- BUILDING NUMBER =26 BUILDING CATEGORY =3 ---------------------------------

                                                SITE     STRUCTURE
                                                         CONCENTRATION

                                                  0             0.000
                                                  1             0.003
                                                  2             0.000
                                                  3             0.000
                                                  4             0.000
                                                  5             0.000
                                                  6             0.000
                                                  7             0.000

--------------------------------------------- BUILDING NUMBER =27 BUILDING CATEGORY =3 ---------------------------------

                                                SITE     STRUCTURE
                                                         CONCENTRATION

                                                  0             0.000
                                                  1             0.000
                                                  2             0.000
                                                  3             0.000
                                                  4             0.000
                                                  5             0.006
                                                  6             0.000
                                                  7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
------------------------------------------ BUILDING NUMBER =28 BUILDING CATEGORY =3 --------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0               0.000
                                                     1               0.000
                                                     2               0.000
                                                     3               0.000
                                                     4               0.000
                                                     5               0.008
                                                     6               0.000
                                                     7               0.000

------------------------------------------ BUILDING NUMBER =29 BUILDING CATEGORY =3 --------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0               0.000
                                                     1               0.003
                                                     2               0.000
                                                     3               0.000
                                                     4               0.000
                                                     5               0.000
                                                     6               0.003
                                                     7               0.000

------------------------------------------ BUILDING NUMBER =30 BUILDING CATEGORY =3 --------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0               0.000
                                                     1               0.007
                                                     2               0.000
                                                     3               0.000
                                                     4               0.000
                                                     5               0.000
                                                     6               0.000
                                                     7               0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
----------------------------------------- BUILDING NUMBER =31 BUILDING CATEGORY =3 --------------------------------

                                        SITE    STRUCTURE
                                                CONCENTRATION

                                          0         0.000
                                          1         0.009
                                          2         0.000
                                          3         0.000
                                          4         0.000
                                          5         0.000
                                          6         0.000
                                          7         0.000

----------------------------------------- BUILDING NUMBER =32 BUILDING CATEGORY =3 --------------------------------

                                        SITE    STRUCTURE
                                                CONCENTRATION

                                          0         0.000
                                          1         0.000
                                          2         0.000
                                          3         0.000
                                          4         0.000
                                          5         0.000
                                          6         0.000
                                          7         0.000

----------------------------------------- BUILDING NUMBER =33 BUILDING CATEGORY =3 --------------------------------

                                        SITE    STRUCTURE
                                                CONCENTRATION

                                          0         0.003
                                          1         0.000
                                          2         0.000
                                          3         0.000
                                          4         0.003
                                          5         0.000
                                          6         0.003
                                          7         0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

------------------------------ BUILDING NUMBER =34 BUILDING CATEGORY =3 ------------------------------

SITE	STRUCTURE CONCENTRATION
0	0.000
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.000

------------------------------ BUILDING NUMBER =35 BUILDING CATEGORY =3 ------------------------------

SITE	STRUCTURE CONCENTRATION
0	0.000
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.003
7	0.000

------------------------------ BUILDING NUMBER =36 BUILDING CATEGORY =3 ------------------------------

SITE	STRUCTURE CONCENTRATION
0	0.000
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.003

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
------------------------------------------- BUILDING NUMBER =37 BUILDING CATEGORY =3 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.000
                                                   1             0.000
                                                   2             0.006
                                                   3             0.005
                                                   4             0.000
                                                   5             0.000
                                                   6             0.000
                                                   7             0.000

------------------------------------------- BUILDING NUMBER =38 BUILDING CATEGORY =3 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.002
                                                   1             0.000
                                                   2             0.004
                                                   3             0.002
                                                   4             0.002
                                                   5             0.000
                                                   6             0.003
                                                   7             0.003

------------------------------------------- BUILDING NUMBER =39 BUILDING CATEGORY =3 ---------------------------------

                                                 SITE    STRUCTURE
                                                         CONCENTRATION

                                                   0             0.003
                                                   1             0.000
                                                   2             0.000
                                                   3             0.000
                                                   4             0.002
                                                   5             0.000
                                                   6             0.003
                                                   7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
--------------------------------------------- BUILDING NUMBER =40 BUILDING CATEGORY =3 ---------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                                0             0.000
                                                1             0.000
                                                2             0.000
                                                3             0.000
                                                4             0.000
                                                5             0.002
                                                6             0.000
                                                7             0.000

--------------------------------------------- BUILDING NUMBER =41 BUILDING CATEGORY =3 ---------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                                0             0.000
                                                1             0.000
                                                2             0.000
                                                3             0.000
                                                4             0.000
                                                5             0.000
                                                6             0.000
                                                7             0.000

--------------------------------------------- BUILDING NUMBER =42 BUILDING CATEGORY =3 ---------------------------------

                                              SITE    STRUCTURE
                                                      CONCENTRATION

                                                0             0.000
                                                1             0.000
                                                2             0.000
                                                3             0.000
                                                4             0.000
                                                5             0.000
                                                6             0.000
                                                7             0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

```
---------------------------------------------- BUILDING NUMBER =43 BUILDING CATEGORY =3 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0             0.002
                                                     1              .
                                                     2              .
                                                     3             0.003
                                                     4             0.000
                                                     5             0.000
                                                     6             0.000
                                                     7             0.000

---------------------------------------------- BUILDING NUMBER =44 BUILDING CATEGORY =3 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     1             0.000
                                                     2             0.000
                                                     3             0.000
                                                     4             0.000
                                                     5             0.000
                                                     6             0.000
                                                     7             0.000

---------------------------------------------- BUILDING NUMBER =45 BUILDING CATEGORY =3 ----------------------------------

                                                   SITE    STRUCTURE
                                                           CONCENTRATION

                                                     0             0.000
                                                     1             0.000
                                                     2             0.000
                                                     3             0.003
                                                     4             0.000
                                                     5             0.003
                                                     6             0.000
                                                     7             0.000
```

```
TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS
           STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS
           AIR SAMPLED.  THE "0" SITE AT EACH BUILDING IS
           ALWAYS THE OUTDOOR LOCATION.  SITES 1-7 DO NOT
           CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES
           A AND B.
---------------------------------------- BUILDING NUMBER =46 BUILDING CATEGORY =3 --------------------------------

                                SITE    STRUCTURE
                                        CONCENTRATION

                                  0            0.002
                                  1            0.000
                                  2            0.000
                                  3            0.000
                                  4            0.000
                                  5            0.000
                                  6            0.000
                                  7            0.005

---------------------------------------- BUILDING NUMBER =47 BUILDING CATEGORY =3 --------------------------------

                                SITE    STRUCTURE
                                        CONCENTRATION

                                  0            0.000
                                  1            0.000
                                  2            0.006
                                  3            0.003
                                  4            0.000
                                  5            0.000
                                  6            0.000
                                  7            0.003

---------------------------------------- BUILDING NUMBER =48 BUILDING CATEGORY =3 --------------------------------

                                SITE    STRUCTURE
                                        CONCENTRATION

                                  0            0.000
                                  1            0.000
                                  2            0.000
                                  3            0.000
                                  4            0.000
                                  5            0.000
                                  6            0.000
                                  7            0.000
```

TABLE G-1. AIR MONITORING DATA LISTING SHOWING THE ASBESTOS STRUCTURE CONCENTRATION (S/CC) AT EACH SITE THAT WAS AIR SAMPLED. THE "0" SITE AT EACH BUILDING IS ALWAYS THE OUTDOOR LOCATION. SITES 1-7 DO NOT CORRESPOND TO THE SITE NUMBERING USED IN APPENDICES A AND B.

-- BUILDING NUMBER =49 BUILDING CATEGORY =3 --

SITE	STRUCTURE CONCENTRATION
0	0.000
1	0.002
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.000

APPENDIX H

GLOSSARY

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ACM: asbestos-containing material.

Air sample: a filter through which a known volume of air has passed in order to measure the asbestos structure concentration in the air during the period of sampling.

Air flow: an air flow transports fibers from the point of release from the ACM to other areas in the building. Air plenums, air shafts and elevator shafts represent different types of air flow.

Air monitoring: the process of collecting air samples in a building.

Asbestos: a group of naturally occurring minerals that separate into fibers. There are six asbestos minerals used commercially (chrysotile, amosite, crocidolite, anthophyllite, tremolite, and actinolite).

Bulk sample: a portion of friable material collected in order to measure the asbestos content of the material.

Categories of buildings:

Category 1--a building in which no friable asbestos-containing surfacing materials or TSI were noted in the GSA records and none was found during the building inspection.

Category 2--a building in which all or most of the areas with friable asbestos-containing surfacing materials or TSI were in good condition allowing for a limited number of areas of moderate damage.

Category 3--a building which had at least one significantly damaged area of friable asbestos-containing surfacing material or TSI, or there were numerous moderately damaged areas.

Condition: See Appendix C for definitions of ACM condition.

Disturbance: (classifications revised March 19, 1987)
High potential for disturbance--ACM which has two or more of the three factors (accessibility, vibration, air erosion) rated "high," or one factor sufficiently high that the material is almost certainly going to be disturbed. Examples are (1) acoustic plaster on a low ceiling in a high school band room; (2) thermal system insulation on air ducts connected to ventilation fans and readily accessible to workers conducting maintenance on the ventilation system; and (3) fireproofing on low beams in a work room located just downstream from an air vent.

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Moderate potential for disturbance--ACM which is accessible, subject to vibration, or subject to air erosion, but has no more than one factor rated as high. ACM on corridor walls, on a ceiling underneath a gymnasium, or in an elevator shaft are examples of material with a moderate potential for disturbance.

Low potential for disturbance--ACM which has low accessibility, is not subject to vibration, and is not subject to air erosion.

External analysis: an analysis in which a sample is analyzed a second time by another analytical laboratory. This type of analysis is performed as a QC check on the performance of the method by the primary laboratory. The degree of agreement of the original analysis with the external analysis indicates the consistency of the method performance.

Field blank: a filter taken into the field, handled in the same manner as exposed air sample filters, and analyzed for contamination which might occur in the field but not as a result of air sampling.

Friable: capable of being crumbled, pulverized, or reduced to powder by hand pressure.

Production lot blank: a filter chosen prior to field work and analyzed by the laboratory to check for filter contamination.

PLM: polarized light microscopy.

Replicate analysis: an analysis in which a sample is analyzed a second time by the same analytical laboratory. The degree of agreement of the original analysis with the replicate analysis indicates the level of precision in the laboratory analysis procedures.

Side-by-side duplicate: a sample collected in the immediate area of the original sample but handled separately. The degree of agreement of the analyses of the original sample with its duplicate indicates the level of precision in the sample collection and field handling procedures.

Structure: An asbestos fiber, bundle, cluster, or matrix.

Surfacing: ACM sprayed or troweled on surfaces, such as acoustical plaster on ceilings and fireproofing material on structural members.

TEM: transmission electron microscopy.

Thermal systems insulation: ACM applied to pipes, boilers, tanks, ducts, etc. to prevent heat loss or gain or water condensation.

TSI: thermal systems insulation.